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Malnutrición y rendimiento neuropsicológico en niños mexicanos

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Malnutrición y rendimiento neuropsicológico en niños mexicanos

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A mi padre,

por enseñarme y dejarme volar

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8.1 Discusión General 113

En general estos resultados son importantes, ya nos muestran la importancia de crear programas nutricionales de prevención y tratamiento efectivos en estas etapas tempranas de la vida, ya que estudios apuntan a que los problemas de alteraciones nutricionales pueden incluso repercutir en la vida adulta (Yehuda, Rabionovitz y Mostofsky, 2006; Walker et al., 2005). Además estos estados nutricios alterados contribuyen a aumentar los costos gubernamentales como la atención de la salud pública y la disminuyen la productividad (McLachlan, 2006); obstaculizando el desarrollo de los países pobres socioeconómicamente hablando (Branca, 2006; Grantham-McGregor et al., 2007). 114

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Caulfield, L.E., de Onis, M., Blössner, M. y Black, R. E. (2004). Undernutrition as an underlying cause of child deaths associated with diarrhea, pneumonia, malaria and measless. American Journal of Clinical Nutrition, 80, 193-198. 121

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Presentación

Según las estimaciones más recientes de la Food and Agriculture Organization (FAO) (2008), el número de personas hambrientas en el mundo, en el período referencia 1990-1992, era de 843 millones de personas, sin embargo para el año 2007 aumentaron a 923 millones, llegando a cifras alarmantes (1,023 millones) en el 2009 (FAO, 2010). En el 2010 se esperaba que se redujera esta cifra a 925 millones (FAO, 2010). Entre las razones expuestas a este aumento, se encuentra la crisis económica mundial y el aumento en los precios en los alimentos amenazando así a largo plazo, la seguridad alimentaria mundial. Estas cifras hacen prácticamente imposible que se logre con éxito la meta mundial de reducir la desnutrición en el 2015 a 420 millones (Food and Agricultures Organization/World Healt Organization, 1992). Agregando en el año 2007 se rompió record de números de países (en total 47) que padecían de crisis alimentaria y que requerían ayuda inmediata (FAO, 2008).

Actualmente, el 80% de los niños desnutridos del mundo viven en tan sólo 20 países (Bryce, Coitinho, Darnton-Hill, Pelletier y Pinstrup-Anderson, 2008). Este problema sigue siendo una gran causa de mortalidad para niños en todo el mundo, se calcula que aproximadamente 10 millones de niños mueren antes de alcanzar los 5 años, y uno de cada 6 niños nace con un bajo peso (Branca, 2006).

En México, datos del 2008 proporcionados por la UNICEF (2009), afirman que el país ocupa el lugar 22 de entre los primeros 24 países con el mayor número de niños menores de 5 años con desnutrición y el único de ellos, que no se encuentra en África o en Asia. Actualmente la tendencia en México sobre la subnutrición es desconocida (FAO, 2010).

Estos datos son alarmantes, debido a las consecuencias, que van desde el riesgo de contraer diversas enfermedades como malaria, diarrea, sarampión y neumonía (Caulfield, De Onis, Blössner, y Black, 2004; Imdad, Sadig y Bhutta, 2011); hasta el aumento en los costos gubernamentales como la atención de la salud pública y la disminución de la productividad (McLachlan, 2006); además de obstaculizar el desarrollo de los países pobres (Branca, 2006; Grantham-McGregor et al., 2007). En el peor de los casos es causa de mortalidad.

Se ha demostrado que cuando la desnutrición ocurre durante la niñez, las capacidades cerebrales son severamente afectadas (Bellisle, 2004; Bryan et al., 2004; Grantham-McGregor et al., 2007), el déficit cognitivo y educativo en niños desnutridos durante la primera infancia, se manifiestan hasta finales de la adolescencia (Walker, Chang, Powell y Mgrantham-McGregor, 2005).

Aunque en las últimas décadas ha aumentado la preocupación por los hábitos alimenticios y la forma en que pueden estar afectando el desempeño escolar y las funciones cognitivas (Fanjiang y Keinman, 2007; Grantham-McGregor et al., 2007). Los resultados de las investigaciones han sido inconclusos o debatibles, es sorprendente la relativa escasez de evidencia sobre las consecuencias del déficit nutricional en el desarrollo (Wachs, 2000). Esta situación se agrava debido a que la mayoría de los países carecen de estadísticas nacionales sobre este tema, lo que no permite identificar la relación que pueden guardar con el desarrollo de los países pobres (Grantham-McGregor, et al., 2007).

Se puede decir que la desnutrición en los niños es el resultado de una dieta pobre, condicionada por diversos factores biológicos, socioeconómicos y culturales (Rivera y Sepúlveda, 2003; Watchs, 2000; Zlotkin, 2006). Entre ellos los altos costos de alimentos nutritivos y la facilidad con que se obtienen los alimentos de mala calidad, deficientes servicios de salud y sanidad, y cuidados paternos inadecuados. Así pues, no cabe duda de que la desnutrición es un problema de las sociedades contemporáneas que afecta más a países subdesarrollados. Por ello resulta cada vez más necesario tener información confiable y oportuna acerca de las características de la nutrición de las poblaciones y se requiere realizar estudios periódicamente para así plantear políticas y programas de intervención pública.

En concordancia con estos hallazgos la realización de esta tesis tiene por objetivo dilucidar la existencia de deterioro neuropsicológico y psicopatológico en niños con desnutrición leve. Y dado que se piensa que las intervenciones nutricionales pueden tener efectos en el desarrollo de las funciones cerebrales durante la infancia (Bryan et al., 2004; Grantham-McCregor, Fernald y Sethuraman, 1999; Zlotkin, 2006), es importante, determinar el efecto en la mejora del rendimiento neuropsicológico mediante la suplementación con los ácidos grasos Omega-3 en niños desnutridos.

Resumen

La tesis consta de un total de ocho capítulos que agrupamos en cuatro secciones (i) introducción, (ii) justificación y objetivos, (iii) memoria de trabajos de investigación (iv) discusión general, conclusiones y perspectivas futuras.

La sección de introducción consta de dos capítulos. En el Capítulo 1 se expone a manera general la relación que guarda la nutrición con el desarrollo cerebral y con diversas habilidades neuropsicológicas. El Capítulo 2 está dedicado especialmente al ácido graso omega-3, tratando aspectos desde su importancia, clasificación, la función de éste en el cerebro, así como una revisión de los estudios sobre los efectos de la suplementación con Omega-3.

La segunda sección contiene el Capítulo 3, en él se encuentra la justificación de la realización de este trabajo así como el objetivo principal, así como los objetivos específicos y las hipótesis que se plantearon.

La tercera sección consta de cuatro capítulos en el que se acogen un conjunto de cuatro trabajos de investigación, los tres primeros dedicados al estudio del CI, aptitudes académicas, habilidades neuropsicológicas y psicopatológicas de los niños desnutridos y uno más referente a los resultados obtenidos sobre las habilidades neuropsicológicas al suplementar a niños desnutridos con Omega-3. En Capítulo 4 se realiza un estudio sobre habilidades académicas y el coeficiente intelectual de los niños desnutridos, los resultados apuntan que los niños con desnutrición leve a moderada, no mostraban diferencias significativas en la inteligencia verbal ni en el desempeño académico.

El Capítulo 5 consiste en estudiar el rendimiento en la función ejecutiva de niños desnutridos, dentro del mismo contexto socioeconómico. Los resultados indican que los dominios neuropsicológicos se vieron afectados, pero que la edad es un factor determinante para ello.

El Capítulo 6 lo constituye un trabajo sobre la presencia de trastornos psicopatológicos asociados a la desnutrición en niños. De manera general los análisis de grupo arrojaron diferencias significativas entre los grupos de niños desnutridos y los niños normales nutridos. Los niños desnutridos, presentan problemas de ansiedad/depresión, quejas somáticas y trastornos de pensamiento son los más frecuentes en las escalas sindrómicas empíricas, indicando mayor prevalencia de trastornos internalizadores. Considerando las escalas orientadas al DSM, los trastornos de ansiedad, los somáticos y los oposicionistas son los más frecuentes en los niños desnutridos.

El Capítulo 7 se trata de una investigación sobre los efectos neuropsicológicos tras la suplementación con el ácido graso Omega-3 en niños desnutridos. En este estudio, los resultados han mostrado una mejoría muy importante en capacidades perceptivas y función ejecutiva después de la suplementación.

La cuarta y última sección contiene el Capítulo 8, en donde se lleva a cabo una discusión general de los hallazgos obtenida a través de los distintos estudios, haciendo especial énfasis en sus implicaciones tanto teóricas como clínicas. Finalmente se presentan las conclusiones y perspectivas futuras de la investigación.

I. INTRODUCCIÓN

Capítulo 1. Nutrición, desarrollo cerebral y funcionamiento neuropsicológico

1.1 Nutrición y desarrollo cerebral

La alimentación de los niños es uno de los factores biológicos más importante en el desarrollo cerebral y cognitivo. Mismos que repercutirán durante toda la vida (McLachlan, 2006), afectando, en la edad escolar las funciones cognitivas (Grantham-McGregor et al., 2007).

Los factores que pueden afectar el desarrollo cerebral y por tanto el desarrollo cognitivo se pueden dividir básicamente en dos: los genéticos y los medio ambientales; la nutrición forma parte de estos últimos (Bryan et al., 2004). Los daños ocasionados por la desnutrición pueden ser temporales (aquellos que se presentan sólo mientras la condición nutricional prevalece), o permanentes (dependiendo del tiempo gravedad y duración de la agresión). Yehuda, Rabionovitz y Mostofsky, (2006), demostraron que el agotamiento en la biodisponibilidad de tirosina en el cerebro detiene la producción de catecolaminas, sin embargo si el daño ocurre en un periodo crítico del desarrollo, puede que las consecuencias no sean temporales sino a largo plazo.

Se llama periodo crítico o periodo más sensible, a cada periodo de la función cerebral y están determinados por la información genética, aunque hay cierto debate, en cuanto a si este período es verdaderamente crítico o es sólo más sensible (Koizumi, 2004). Estos períodos descubiertos por Hubel y Wiesel (1970), representan mayor plasticidad cerebral, y experiencia sensorial, generando cambios permanentes en los circuitos neuronales (Ito, 2004).

El mayor interés de los estudios sobre las deficiencias nutricionales en los niños radica principalmente en las carencias proteico-energético, deficiencia de hierro y ácidos grasos esenciales (Yehuda, Rabinovitz y Mostofky, 2006), y muchos de estas investigaciones tienden a concentrarse en el último tercio de gestación y los primeros dos años de vida, pues se considera que es cuando el cerebro se desarrolla aceleradamente, llegando a tener el 80% del peso que tendrá de adulto (Benton, 2008). Sin embargo recientemente se ha llegado a la conclusión de que la maduración cerebral no se ha completado en esta etapa y además no es uniforme (Yeduha, Rabinovitz y Mostofsk, 2006). Hay evidencias de que el cerebro sigue desarrollándose a lo largo de la infancia, durante la niñez y, hasta la adolescencia (Ito, 2004). Más allá aún, autores como Benton (2008) mencionan que, el cerebro de los adultos puede adaptarse a circunstancias cambiantes.

Se ha reportado que las áreas que regulan la cognición, área del cortex frontal y prefrontal (que regulan la función ejecutiva) y el hipocampo (que regulan el aprendizaje, la memoria, la emoción, el lenguaje y la atención), son las que maduran al último y no terminan su proceso de maduración sino después de la infancia, (Romine y Reynolds, 2004). Por otro lado algunos investigadores piensan que la corteza frontal madura finalmente a los 10 años (Yeduha, Rabinovitz y Mostofsk, 2006). Algunas habilidades como el pensamiento abstracto, razonamiento deductivo y la capacidad para resolver problemas se desarrollan durante la adolescencia, etapa que representa también un periodo crítico (Benton, 2008).

Existen varios indicadores para la maduración del cerebro, como la sinaptogénesis, la formación de la mielina y la formación de las dendritas (Bryan et al., 2004). La desnutrición ocasiona la reducción en los ciclos de la división neuronal y de las conexiones dendríticas (Uauy y Mena, 2001).

Finalmente hay que considerar que otros estudios sugieren que la desnutrición puede afectar estructuras como el hipocampo (Watchs, 2000) y los niveles de neurotrasmisores como la dopamina, la serotonina, la norepinefrina y la acetilcoloina, en regiones específicas del cerebro (Uauy y Mena, 2001) que pueden llegar a repercutir en el desarrollo cognitivo. Los niños desnutridos tienen menos logros en la escuela, sus avances son lentos (Maclachlan, 2006).

1.2 Nutrición y su relación con el desempeño neuropsicológico en niños

Una buena dieta ayuda a un adecuado desarrollo, mientas que una dieta inadecuada tiene el potencial para influir negativamente en el crecimiento del cerebro (Benton, 2008). Es quizá por ello que los estudios sobre la relación entre la nutrición y el desempeño neuropsicológico ha ido aumentando en los últimos 50 años (Fanjiang y Keinman, 2007).

Existen dos formas en que la dieta puede influir en la cognición: la primera es a corto plazo y directamente sobre las funciones cognitivas del niño, mediante la provisión de energía o la eficiencia con la que se utiliza, y la segunda a largo plazo, sobre las estructuras cerebrales durante el crecimiento (Benton, 2008).

La omisión del desayuno es una de las prácticas más comunes durante la infancia y se ha observado que tomar un desayuno adecuado es una de las formas de beneficiar a corto plazo las habilidades neuropsicológicas. Por ejemplo, Mahoney, Taylor, Kanarek y Samuel (2005), encontraron que los niños de 9 a 11 años que desayunan, mejoran el desarrollo cognitivo una hora después de consumir los alimentos, en comparación con los niños que ayunan. Además los niños que consumían avena en vez de cereal, mostraron mejora después de consumirla, en la memoria espacial y en la memoria a corto plazo (Mahoney et al., 2005). En otro estudio, se comprobó que el decremento de la atención y de la memoria durante la mañana fue menor en los niños que desayunan cereales que los que ayunaban o los que sólo habían consumido glucosa (Wesnes, Pincock, Richardson, Helm y Hails (2003).

La práctica constante de una alimentación sana, también tiene sus beneficios a largo plazo. En un estudio se encontró que los bebés que se alimentan con frutas, verduras, alimentos ricos en almidón, carne y pescado, a la edad de cuatro años tendían a ser un poco más inteligentes (Gale et al., 2008). Incluso investigaciones también muestran que la leche materna prolongada pude mejorar el desarrollo cognitivo (Kramer et al., 2008).

Actualmente, no se conocen con exactitud las cantidades mínimas requeridas de nutrientes para lograr un desarrollo cerebral adecuado en las etapas gestacionales, ni el grado de malnutrición, o el tiempo para que se produzcan alteraciones a largo plazo e irreversibles (Garofalo, Gómez, Vargas y Novoa, 2009). No obstante, autores como Bryan (2004), han reportado los principales micro-nutrientes que influyen en el desarrollo cognitivo tales como el hierro, yodo, acido fólico, zinc, vitamina b12, y omega.3.

- La deficiencia de acido fólico, influye sobre el rendimiento cognitivo (Bryan, 2004), especialmente en la memoria episódica de adultos (Hassing, Wahlin, Winblad y Backman, 1999). Los niños sanos que tienen un alto consumo de ácido fólico muestran mayores niveles de coeficiente intelectual (Arija et al., 2006).
- La falta de yodo puede ocasionar disfunción motora y cognitiva (Zimmermann et al., 2006).
- La carencia de hierro ocasiona daños en la función ejecutiva (Bryan, 2004) y, en general el rendimiento cognitivo es más pobre (Garofalo et al., 2009; Lozoff, Jimenez, Hagen, Mollen y Wolf, 2000). Los niños sanos que tienen un alto consumo de hierro, muestran mayores niveles de coeficiente intelectual (Arija et al., 2006).
- El zinc es un micronutriente ampliamente relacionado con el crecimiento y desarrollo. Además de que su deficiencia se asocia a la replicación de genes se piensa que puede afectar el desarrollo motor, la atención y el comportamiento neuropsicológico y en conjunto otros nutrientes afecta al rendimiento cognitivo (Bryan, 2004).

- Las vitaminas del complejo energético, particularmente B1, B6 y B12, tienen una clara repercusión en el rendimiento cognitivo (Bryan, 2004). En específico la deficiencia de vitamina B12 afecta la memoria (Hassing et al., 1999), mientras, la carencia de vitamina B6 en neonatos puede producir déficit cognitivo (Garofalo et al., 2009).
- Los estudios muestran que la deficiencia de los ácidos grasos omega-3 repercuten en la agudeza y el reconocimiento visual, la memoria y las habilidades cognitivas (Bryan et al., 2004), y en general en el desarrollo cognitivo (Kirby, Woodward y Jackson, 2009). El déficit de estos ácidos grasos no ocurre solamente por la falta de ingesta, sino también al exceso en el consumo de los ácidos grasos omega 6. Esto se debe a que ambos comparten la actividad de las desaturasas, de tal manera que los omega 6 actúan como inhibidores competitivos, disminuyendo la desaturación y elongación de acido alfalinolenico (omega 3) en acido docosahexaenoico y eicosapentaenoico (Kirby, Woodward y Jackson, 2010).

Todas estas deficiencias son consideradas carencias específicas que por sí mismas, sin coexistir con desnutrición calórico proteica, pueden ejercer efecto sobre aspectos del desarrollo relacionados con procesos cognitivos. Debe considerarse por lo tanto que el déficit de carbohidratos, entre otros, también puede afectar al rendimiento cognitivo (Benton, 2008).

Entre las alteraciones por malnutrición, se ha estudiado ampliamente la relación de la desnutrición global o especifica con las alteraciones en el desarrollo durante la infancia. Sin embargo son igualmente importantes, por su magnitud y trascendencia las relacionadas con el exceso. La sobreingesta calórica no implica necesariamente un aporte adecuado de micronutrientes, por lo general las dietas altas en energía o grasas suelen ser deficitarias en vitaminas y minerales y excesivamente altas en grasas de tipo saturadas y trans, mientras que la ingesta de grasas monoinsaturadas y omega 3 es habitualmente baja. La práctica de estos hábitos nutricionales desfavorables tiene que ver con los cambios que durante los últimos años se han operado en nuestro medio, debido al incremento en la disponibilidad de alimentos altamente energéticos, expendidos en restaurantes de comida rápida. Las malas prácticas alimentarias no son exclusivas del infante mayor, ya durante la lactancia, la alimentación al seno materno ha ido cada vez más en desuso, aun cuando se sabe que la leche materna puede reducir el riesgo de sobrepeso en la infancia (Fanjiang y Kleinman, 2007).

El exceso en el consumo de calorías conduce al desarrollo de la obesidad. La obesidad es considerada en la actualidad una enfermedad con efectos negativos sobre varios sistemas metabólicos que pueden contribuir al deterioro del CI (Gustafson, 2006). Un trastorno que con frecuencia se presenta en los niños obesos es la apnea del sueño, son episodios momentáneos de hipoxia, cuyo alcance es determinante en los procesos cognitivos del niño. En México coexiste la obesidad, con un ritmo acelerado de incremento en la prevalencia, y la desnutrición que no ha podido ser erradicada. Esto hace necesario analizar el impacto de ambas sobre el desarrollo integral de la población infantil, que representa el futuro de las sociedades.

En resumen, se reportan numerosas evidencias que relacionan la mejora del estado nutricional en los niños no sólo con una mayor expresión del potencial genético de crecimiento y desarrollo sino también con importantes beneficios neuropsicológicos y cognitivos (Neumann, Murphy, Gewa, Brillenberger, y Bwibo, 2007). Eso ha motivado que se realicen numerosos estudios de suplementación buscando las mejorías neuropsicológicas en los niños desnutridos.

Capítulo 2. Suplementación con Omega-3

2.1 Importancia de los ácidos grasos

Desde que Burr y Burr en 1929 (citado en Caster, Andrews, Mohrhauer y Holman, 2009) descubrieron que los ácidos grasos son esenciales en la nutrición, se ha continuado haciendo estudios sobre este tema, sin embargo. Durante las últimas dos décadas ha incrementado el interés por estudiar el papel que juega la nutrición en los problemas de aprendizaje y comportamiento, especialmente en relación con los ácidos grasos Omega-3 (ω-3) y Omega-6 (ω-6) (Johnson, Östlund, Fransson, Kadesjö y Gillberg, 2009). Aunque el tejido cerebral es altamente dependiente de glucosa para la obtención de energía y ocasionalmente, bajo determinadas circunstancias puede sobrevivir a base del aporte de cuerpos cetonicos, las grasas resultan esenciales como componentes estructurales. Por ello es necesario el aporte adecuado de ambas moléculas y para mantener las funciones cerebrales normales (Yehuda, Rabionovitz y Mostofsky, 2005) y su deficiencia afecta el desempeño de las habilidades cognitivas.

Los ácidos grasos poliinsaturados deben ser aportados por la dieta ya que el organismo no los produce y debido a ello se les llama ácidos grasos esenciales (AGE). La mayor parte de los fosfolípidos de las membranas en el tejido cerebral están constituidos por acidos grasos omega 3, de ahí la importancia de estos como elementos estructurales cerebrales. Por otra parte los PUFA's dan lugar a la síntesis de eicosanoides como las prostaglandinas, leucotrienos y tromboxanos que regulan los procesos inflamatorios, inmunes y el tono vasomotor. Desde hace algún tiempo se sabe que el aporte adecuado de ácidos grasos omega 3 es esencial para el buen desarrollo cerebral durante la gestación y el primer año de vida.

2.2 Clasificación de los ácidos grasos y su consumo

Los ácidos grasos que forman parte de la dieta se clasifican en saturados e insaturados. Existen tres grupos de ácidos grasos insaturados: el omega-9 (ω-9), que pertenecen al grupo de los monoinsaturados y los ω-6 y ω-3, que forman parte de los poliinsaturados. Existe otro tipo de grasas que son producto de la hidrogenación industrial y se denominan ácidos grasos trans. Para fines prácticos, estos se incluyen en el grupo de saturados por la similitud de sus efectos metabólicos. Los ω-9 se encuentran principalmente en el aceite de oliva; los ω-6 están presentes mayormente en plantas en particular, en los aceites de semillas (Youdim, Martin y

Joseph, 2000) como girasol, maíz, soja y aceite de cártamo (Innis, 2008), mientras que los ω-3 se encentran en mayores proporciones en pescados, principalmente en el salmón, la trucha y el atún (Surette, 2008).

El ácido graso linoleico y alfa linolenico (omega 6 y 3 respectivamente), por la acción de enzimas desaturasas dan lugar a ácidos grasos de cadena muy larga como el acido araquidónico, sintetizado a partir del linoleico y los acidos docosahexaenoico (DHA) y eicosapentaenoico (EPA), a partir del alfalinolenico. Estos a su vez producen por oxidación los eicosanoides. Los ácidos linoleico y alfalinolenico pueden competir por las desaturasas que dan lugar a los ácidos grasos de cadena muy larga, de tal manera que es necesario mantener una proporción adecuada de su ingesta para evitar el bloqueo en la síntesis de DHA y EPA.

En la dieta no mediterránea se abusa del consumo de ácido linoleico (ω-6, presente mayormente en el aceite de girasol) si se ingiere en cantidades superiores a las recomendados, ocasiona repercusiones negativas sobre la adecuada utilización de los ácidos grasos ω-3 (Mataix y Gil, 2004). En la población de niños mexicanos de 1 a 4 años en particular, se encontró un alto consumo de aceite vegetal y por tanto del ácido graso trans, que interfieren con el metabolismos de los ácidos grasos esenciales pueden tener también efectos adversos sobre el crecimientos y desarrollo infantil (González-Castell, González-Cossio, Barquera y Rivera, 2007). A decir de estos autores, esto se vuelve más grave, si se reduce la ingesta de los ácidos grasos esenciales.

La principal fuente de aporte de ω-3, es el pescado o de suplementos alimenticios (Surette, 2008). Sin embargo la dieta occidental contiene poca cantidad de omega-3 (Ballesteros, Sejas, Herbas y Carpentier, 2007) y alta ω-6 (Innis, 2008). Además la ingesta del ácido linoleico se ha incrementado drásticamente en el último siglo (Novak, Dyer e Innis, 2008) debido en gran medida a la incorporación del aceite vegetal a la vida moderna (Simopoulos, 2002).

Particularmente en México se consumen pocos alimentos que contienen ω-3. Datos de las encuestas de alimentación, revelan que el consumo de pescado es de 16.2 g/per cápita a nivel nacional y sólo el 18.7% de las familias los consumen de una a dos veces a por semana (Ávila, Shamah, Chávez y Galindo, 2002), además, los niños en edad escolar consumen porciones muy bajas de pescado (Ortiz y Ramos, 2008). Todo esto a pesar de ser un país con 11,122 km de longitud costera y 200 millas de ancho que corresponde a la zona económica exclusiva (SAGAR, 1995). Así que debido a la situación geográfica, el alto costo y la poca variedad de estos alimentos, además de que culturalmente no existe la costumbre de ingerirlos (Ortiz y Ramos, 2008), se podría inferir que en la población del estado de Chihuahua existe deficiencia de ω-3. En cambio, datos aportados por López-Alvarenga et al., (2007) indican que alimentos ricos en grasa saturada como las fritangas (carnitas y antojitos), papas fritas, pasteles, tacos, tortas, son consumidos en todos los estratos económicos y en cantidades importantes.

2.3 Actividad de los ácidos grasos en el cerebro.

En particular los ácidos grasos poliinsaturados (PUFAs) son importantes para producir energía en el cuerpo. Se ha demostrado que estos ácidos grasos pueden actuar como ligados de factores de transcripción, promoviendo el incremento en la producción de enzimas encargadas de la oxidación. De tal manera que son utilizados preferentemente en rutas oxidativas para la producción de energía (Yehuda et al., 2002). Sin embargo como se ha mencionado anteriormente, el cerebro obtiene la energía a partir de glucosa y cuerpos cetónicos, los ácidos grasos poliinsaturados son más importantes como estructuras de membrana, particularmente los omega 3. Es por eso que los aceites de pescado son los que ejercen más influencia en las concentraciones de PUFA el cerebro (Youdim, Martín y Joseph, 2000).

Existen dos tipos de PUFA esenciales (AGE); el ácido linoleico y el ácido alfa-linolénico (Yeduha, Rabinovitz y Mostofsky, 2005), que son esenciales para el desarrollo y mantenimiento del cerebro (Yeduha, Rabinovitz y Mostofsky, 2006). Los omega-3 tienen un efecto en el índice de fluidez de la membrana neuronal, al mantener una función adecuada de canales iónicos y receptores de membrana, que permiten el intercambio adecuado en las células. (Yeduha, Rabinovitz y Mostofsky, 2005). Los omega-3 contribuyen también como precursores de segundos mensajeros que son necesarios para la transducción de señales intracelulares. La disminución de la fluidez de la membrana, hace difícil que la célula lleve a cabo sus funciones normales y aumenta la susceptibilidad a las lesiones y muerte de la misma (Yehuda, Rabinovitz, Carasso y Mostofsky, 2002).

La actividad del cerebro depende en gran medida de la integridad de la membrana neuronal (Uauy y Mena, 2001), la vaina de mielina, la membrana que rodea y el compuesto de la mielina que están constituidas por lípidios (Yeduha, Rabinovitz y Mostofsky, 2006). Las lesiones o ruptura de la mielina pueden conducir a la desintegración de muchas funciones del sistema nervioso (SN), así pues la integridad de la mielina es de suma importancia para las funciones propias de los axones del sistema nervioso y los AGE son importantes también en la fase activa de la síntesis de la mielina. (Yehuda, Rabinovitz y Mostofsk, 2005). Los ácidos grasos en las membranas celulares son los que afectan la función celular (Yeduha, Rabinovitz y Mostofsk, 2005). Se cree que muchas funciones y respuestas celulares pueden ser afectadas, si se modifica la membrana lipídica (Youdim, Martín y Joseph, 2000).

Concretamente, la deficiencia de Omega-3 (alfalinolenico), que participan en los procesos de división celular, disminuye significativamente el tamaño de las neuronas del hipocampo, el hipotálamo y la corteza (Yehuda, Rabinovitz y Mostofsky, 2006). También inducen una significativa reducción de catecolaminas, que afectan el trasporte de la glucosa y la utilización de ésta en el cerebro. Todas estas variables repercuten en el aprendizaje y, ocasionan la disminución del Acido decosahexaenoico (DHA) y el incremento de los niveles de DPA, producto final del ω-6 (Uauy y Mena, 2001). Además el ω-3 desempeña un papel importante en las funciones cerebrales, pues mantiene en óptimas condiciones a las membranas neurales, permite la fluidez de la membrana y ayuda a conservar su espesor (Uauy y Mena, 2001).

El DHA, formado a partir del grupo ω-3, es el ácido graso más abundante en el cerebro concentrado particularmente en las células nerviosas sinápticas donde parece ser que participan en los procesos y señalización de las células neuronales (Youdim, Martín y Joseph, 2000) o trasducción de señales, controla la actividad de los neurotrasmisores y los factores de crecimiento neuronal (Yehuda et al., 2002), y es componente de la materia gris cerebral (Innis, 2008). El DHA y el AA son los principales ácidos en los fosfolípidos de la membrana de la célula, especialmente en la materia gris que comprende el 6% de su peso en seco. Parece ser que el nivel de DHA es crucial para las funciones cognitivas normales, cualquier desviación de sus niveles fisiológicos se asocia con deterioro cognitivo (Yehuda, Rabionovitz y Mostofsky, 1999). Mientras que el ácido eicosapentaenoico (EPA) está presentes en muy baja concentración en el tejido nervioso (Gadoth, 2008). Además, se cree que el EPA es precursor del DHA y desempeña un papel importante en el cerebro (Sinn y Bryan, 2007).

Respecto a la actividad de algunos neurotrasmisores, se sabe que los omega 3 participa en la síntesis de algunos de ellos como la acetilcolina, esencial para la transmisión de los impulsos nerviosos, la serotonina y la dopamina que influyen en el equilibrio de las emociones y en las emociones positivas. La deficiencia de ω-3, ocasiona reducción de la dopamina en el área de la corteza (Yehuda, Rabionovitz y Mostofsky, 2005).

2.4 Estudios con suplemento Omega-3 y neuropsicología

Se piensa que las intervenciones nutricionales pueden tener efectos en el desarrollo de las funciones cerebrales durante la infancia (Grantham-McCregor, Fernald, Sethuraman, 1999; Bryan et al., 2004; Zlotkin, 2006).

La trascendencia que representa el adecuado desarrollo cognitivo y el aprendizaje en la infancia, ha incrementado el interés por los estudios de intervención, particularmente aquellos que ponen en práctica la suplementación con omega 3. Recientemente ha incrementado el número de publicaciones relacionadas con el suplemento de ω-3 sobre la cognición. El primero de este tipo fue el realizado por Richardson y Puri (2002), quienes realizaron un estudio aleatorio, doble ciego, controlado con placebo sobre los efectos de los ácidos grasos insaturados en niños de 8 a 12 años, con presunto TDAH. Los resultados indicaron que la suplementación con PUFA ofrece un beneficio significativo para aliviar muchos síntomas relacionados con el TDAH en niños con dificultades específica de aprendizaje como dislexia.

En contraste Hirayama, Hamazaki y Terasawa (2004), no encontraron mejorías significativas en su estudio realizado en niños de 6 a 12 años con TDAH. A diferencia de otros estudios, ellos no suplementaron con cápsulas sino que aumentaron en un grupo los de alimentos con DHA /EPA en la dieta y un segundo grupo con placebo (alimentos ricos en aceite de oliva). Un punto importante, aparte de que no tomaron en cuenta la gravedad de los síntomas, es que la duración de la intervención fue de sólo 2 meses a diferencia de la mayoría de los estudios como el de Richarson y Puri (2002) o el de Richardson y Motgomery, (2005), donde suplementaron por mayor tiempo.

Posteriormente los primeros autores perfeccionaron su anterior estudio, considerado como uno de los más importantes que ha servido de base para otras investigaciones. Este nuevo estudio es el Oxford-Durhan (Richardson y Motgomery, 2005), el cual se realizó con 117 niños de 5 a 12 años, que tuvieran problemas en el desarrollo motor, fue llevado de manera aleatoria, doble ciego y controlado con placebo en grupos paralelos durante 3 meses, seguido por un corte (de placebo a tratamiento activo) por un período adicional de 3 meses. El suplemento alimenticio contenía ω-3 y ω-6, (80% de aceite de pesado y 20% de aceite de onagra). Ellos no encontraron mejoras significativas en las habilidades motoras, sin embargo en lectura, ortografía y en el comportamiento si encontraron diferencias.

Para seguir con la revisión de estos estudios, el de Sinn y Bryan (2007), en el cual incluyeron a 104 niños de entre 7 y 12 años de edad con TDAH que vivían en Australia. La investigación fue aleatoria, controlada con placebo. El suplemento administrado contenía 400mg de aceite de pescado 93mg de EPA, 29mg de DHA, 10mg de (GLA), 1,8 mg de vitamina E; el placebo contenía aceite de palma. A todos se les daba también una multivitamina mineral. Los resultados en la fase uno, fueron significativos en la comparación de los PUFAs con el placebo en la cognición, inatención, la hiperactividad y la impulsividad. En la segunda fase el grupo placebo mostró mejoras significativas en la cognición, hiperactividad y la impulsividad. No hubo beneficios de las multivitaminas minerales por encima de los PUFAs.

Recientemente se publicó el estudio de Kakiraluloma, Närhi, Ahonen, Westerholm y Aro (2008). Ellos realizaron un estudio con niños disléxicos, a los que se les administraba a un grupo EPA (500 mg al día) y carnosine (400 mg al día) y placebos al grupo control. En sus resultados no encontraron diferencias entre los grupos, en el desarrollo de la precisión de lectura, en la velocidad, la exactitud de ortografía, en fluidez de decodificación o en las relacionadas con la lectura ni conocimientos lingüísticos. Tampoco encontraron diferencias entre los grupos en la lectura ni en relación a las competencias lingüísticas (procesamiento fonológico, memoria verbal a corto plazo), habilidades aritméticas, de atención ni en problemas de comportamiento. Aunque los niños en ambos grupos mejoraron en la mayoría de las medidas durante el tratamiento, esta mejora la explican debido al desarrollo normal del niño, al efecto placebo y a la repetición de la prueba.

En niños autistas, se encontró que al suplementaros con aceites de pescado ricos en EPA, mejoraron la salud en general, encontraron mejoras cognitivas, en habilidades motoras, en la concentración, sociabilidad, las infecciones redujeron, así como la irritabilidad, la agresión y la hiperactividad (Bell et al., 2004).

En relación a la suplementación de omega-3 en conjunto con otros micronutrientes en un estudio llevado a cabo en la India, con niños marginalmente alimentados. No encontraron diferencias entre los niños que se les dieron bajo omega-3 y los que consumieron altos omega-3 además de los micronutrientes, en ninguna habilidad cognitiva (Muthayya et al., 20009). Los autores argumentaron que la falta de efectos significativos tal vez se deba a que las dosis eran bajas o a que los dominios evaluados no tengan relación con el DHA o los micronutrientes administrados.

Aunque en recientes estudios en personas sanas, los niños bien nutridos no muestran mucho beneficio por la administración de suplementos de ácidos grasos (Kirby et al., 2010) u otros micronutrientes (Fanjiang y Keinman, 2007), sí se muestran resultados favorables en niños desnutridos. Por ejemplo, Walker et al. (2005), en su estudio realizado en Jamaica con niños desnutridos, concluyeron que la administración de suplementos nutricionales tiene resultados favorables sobre el desarrollo cognitivo posterior.

En resumen, los ácido grasos poliinsaturados juegan un papel crucial en el desarrollo del cerebro (especialmente en la estructura de la membrana) y numerosos estudios han mostrado que se producen una mejora cognitiva tras su ingesta o una disminución de capacidades ante su déficit.

II. JUSTIFICACION Y OBJETIVOS

Capítulo 3. Justificación y objetivos de la tesis.

3.1 Justificación y objetivo general de la tesis

Como se ha mostrado en la revisión bibliográfica, es sabido que el rendimiento neuropsicológico de los niños está muy relacionado con su estado nutricional. Son numerosos los estudios que han demostrado que la deficiencia en la ingesta de micronutrientes como el hierro (Rico et al., 2006; Falkingham, 2010), iodo (Gordon et al., 2009) o el zinc (Rico et al., 2006; Hamadani et al., 2001) repercute en la baja ejecución neuropsicológica de los niños.

Por otro lado, numerosos estudios han estudiado los posibles beneficios del uso del ácido omega 3 en niños con problemas del neurodesarrollo como TDAH, problemas de desarrollo motor, disléxico y en autistas con resultados contradictorios (Bell et al., 2004 ; Levant, Zarcone y Fowler, 2010 ; Kakiraluloma et al., 2008; Richardson y Motgomery, 2005 Richarson y Puri, 2002; Sinn y Bryan, 2007).

Aunque en recientes estudios en personas sanas, los niños bien nutridos no muestran mucho beneficio por la administración de suplementos de ácidos grasos (Kirby et al., 2010) u otros micronutrientes (Fanjiang y Keinman, 2007), sí se muestran resultados favorables en niños desnutridos. Por ejemplo, Walker et al. (2005), en su estudio realizado en Jamaica con niños desnutridos, concluyeron que la administración de suplementos nutricionales tiene resultados favorables sobre el desarrollo cognitivo posterior.

Sin embargo, la mayoría de estos trabajos no han medido el rendimiento cognitivo con baterías amplias que exploren el conjunto de las funciones neuropsicológicas. Esto puede tener un doble efecto negativo. En primer lugar, llevar a la obtención de resultados negativos en los estudios si las pruebas utilizadas no son lo suficientemente sensibles y específicas. En numerosos estudios citados, la principal medida de éxito fue el incremento en el CI. En segundo lugar, si la suplementación produce efectos específicos en ciertas áreas funciones neuropsicológicas, sólo podrán ser detectados utilizando baterías amplias con pruebas específicas de cada función.

Hasta donde nosotros conocemos, no se ha realizado ningún estudio de suplementación con omega 3 en México ni en el ámbito latinoamericano. Por tanto el objetivo principal de esta Tesis Doctoral ha sido investigar el rendimiento neuropsicológico de los niños con desnutrición leve y probar el efecto de la suplementación con el ácido graso omega-3 en la mejora del su rendimiento neuropsicológico.

3.2 Objetivos específicos e hipótesis

Para lograr el objetivo general se propusieron objetivos específicos abordados en los cuatro estudios de esta Tesis:

1. El primer objetivo fue investigar si la desnutrición leve a moderada, afecta a la inteligencia y al rendimiento académico en una población de niños mexicanos, controlando variables como el estatus socioeconómico, el nivel educativo y la inteligencia de las madres; dichas variables están muy asociadas con la presencia tanto de desnutrición como de obesidad. Hipotetizamos que en esta muestra se replicarán los resultados internacionales y que tanto los niños con desnutrición leve a moderada como los niños obesos, mostrarán menor inteligencia y menor rendimiento académico que los niños controles.

El objetivo de este estudio es doble. En primer lugar, conocer si se replica en la población de estudio, los resultados internacionales relacionando la desnutrición con una baja inteligencia. En segundo lugar, comparar los resultados de los niños desnutridos con los niños obesos para responder a distintas demandas: (i) unirnos a la creciente línea de investigación que demuestra que desnutrición y obesidad son dos fenómenos unidos en los países en vías de desarrollo (Iriart, Handal, Boursaw, y Rodrigues, 2011; Uauy, Kain, Corvalan, 2011;) y (ii) devolver información a los colegios sobre la severidad y frecuencia de los hallazgos neuropsicológicos en ambos grupos para que ellos puedan planificar y priorizar los recursos escolares.

Los resultados de este estudio se han enviado a publicar a la revista *Journal of Child Neurology (*Portillo-Reyes, V., Loya-Méndez, Y., Perales, J.C., Pérez-García, M., Antonio Puente). Se encuentra íntegramente en el Anexo I.

2. Tras la investigación anterior se identificó la necesidad de analizar a profundidad los posibles deterioros neuropsicológicos profundizando en un áreas específicas como lo

es la función ejecutiva y en la salud mental que conlleva la desnutrición. Por esto, se llevaron a cabo dos estudios:

2.1. Investigar si la desnutrición en grado leve-moderado conlleva alteraciones neuropsicológicas focalizando la investigación en el área de las funciones ejecutivas. Hipotetizamos que la función ejecutiva estará alterada en los niños desnutridos en comparación con los niños normopeso.

Decidimos focalizar la investigación exclusivamente en la función ejecutiva debido a que (i)a la edad en que los niños fueron evaluados, existe un período crítico para estas funciones y (ii) debido al impacto que una posible alteración en dichas funciones tiene en el comportamiento del niño.

Los resultados de este estudio se han enviado a la revista *Journal of School Health* (Portillo-Reyes, V., Puente, E. A., Pérez-García, M. y Loya-Méndez, Y., 2011). Se encuentra íntegramente el Anexo II

2.2. Investigar si la desnutrición en grado leve a moderada tiene asociado algún patrón psicopatológico de deterioro. Las alteraciones psicopatológicas infantiles tienen un alto impacto en el funcionamiento de los niños y, sin embargo, esto ha sido muy poco estudiado en los niños desnutridos. Hipotetizamos un patrón de deterioro psicopatológico específico en los niños con desnutrición leve a moderada en comparación con los niños normopeso.

Los resultados de este estudio se han enviado a la revista *Actas Españolasl de Psiquiatría*. (Portillo-Reyes, V., Pérez-García, M., Puente, E. A., Loya-Méndez, Y., 2011). Se encuentra íntegramente el Anexo II

3. El tercer objetivo fue investigar si la suplementación con el ácido Omega-3 mejora las funciones neuropsicológicas de los niños con desnutrición leve a moderada. Hipotetizamos que los niños con desnutrición, presentarán una mejoría clínicamente

relevante en comparación con el grupo control y con el grupo placebo en distintas áreas neuropsicológicas.

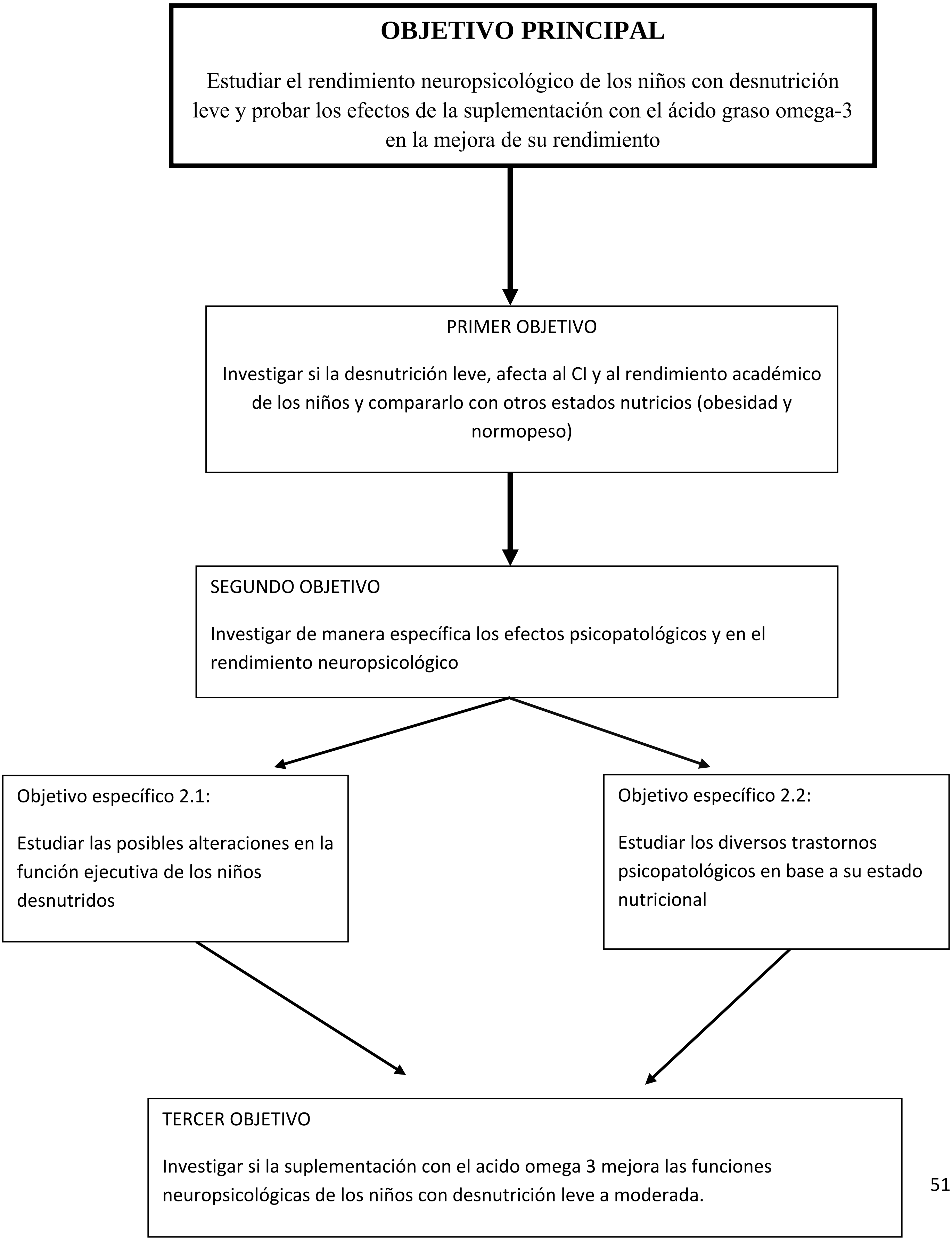
Como colofón de esta serie de estudios, se decidió estudiar los posibles beneficios neuropsicológicos que pueda ofrecer el suplemento Omega-3, en niños desnutridos. Se decidió suplementar exclusivamente con omega 3 por varias razones: (i) los estudios nutricionales en la región apuntan a un potencial déficit de omega 3 debido al bajo consumo de pescado en esa zona; (ii) aunque son diversos los nutrientes relacionados con las funciones neuropsicológicas (Bryan et al, 2004), son muy escasos los estudios con suplementación de omega 3 en niños desnutridos; (iii) hasta donde nosotros sabemos, no existen estudios de suplementación en niños mayores (8-12años). A esa edad, la ventana crítica de desarrollo es para la función ejecutiva y algunos estudios han mostrado relación entre el déficit de omega 3 y la disminución de la dopamina en la corteza cerebral (Yehuda, Rabinovitz y Mostofsk, 2005). Por tanto, seleccionamos el omega 3 como el mejor suplemento que podía influir en la función ejecutiva.

A pesar de que hipotetizamos una mejora en la función ejecutiva, se aplicará una batería amplia para detectar otras posibles mejorías.

Los resultados de este estudio se han enviado a publicar a la revista The American Journal of Nutrition (Portillo-Reyes, V., Pérez-García, M., Loya-Méndez, Y., Puente, E. A., 2011).

De modo gráfico, la secuencia de los estudios se puede ver en la Figura 1

Figura 1.


OBJETIVO PRINCIPAL
Estudiar el rendimiento neuropsicológico de los niños con desnutrición leve y probar los efectos de la suplementación con el ácido graso omega-3 en la mejora de su rendimiento
PRIMER OBJETIVO
Investigar si la desnutrición leve, afecta al CI y al rendimiento académico de los niños y compararlo con otros estados nutricios (obesidad y normopeso)
SEGUNDO OBJETIVO
Investigar de manera específica los efectos psicopatológicos y en el rendimiento neuropsicológico
Objetivo específico 2.1:
Estudiar las posibles alteraciones en la función ejecutiva de los niños desnutridos
Objetivo específico 2.2:
Estudiar los diversos trastornos psicopatológicos en base a su estado nutricional
TERCER OBJETIVO
Investigar si la suplementación con el acido omega 3 mejora las funciones neuropsicológicas de los niños con desnutrición leve a moderada.

III. MEMORIA DE TRABAJOS

Capítulo 4. *Low non verbal intelligence and academic skills in Mexican obese children versus malnourished.*

Portillo-Reyes, V., Loya-Méndez, Y., Perales, J.C., Pérez-García, M., Antonio Puente. Low non verbal intelligence and academic skills in Mexican obese children versus malnourished. *Journal of Child Neurology*, under review.

4.1 Introduction

Child obesity has also increased substantially in recent decades and is now considered an epidemic (Sigfúsdóttir, Kristjánsson y Allegrante, 2007), and in some cases, even a pandemic (Malecka-Tendera y Mazur, 2006), especially in Latin America (Amigo, 2003). This trend of obesity is particularly prevalent in Mexico. According to published data from the National Survey of Health and Nutrition (ENSANUT) (Olaiz et al., 2006), the prevalence of overweight and obese children of ages 5 to 11 in Mexico, using the criteria of the International Obesity Taskforce (IOTF), was around 26% for both sexes. Also northern Mexico had the greater prevalence of obese children (Bacardí-Gascón, Jiménez-Cruz y Guzmán-González, 2007).

However, currently obesity and malnutrition are one of the biggest crises in developing countries because they are occurring simultaneously (Zlotkin, 2006). This problem may be related to a significant pattern of poor eating habits. Data in Mexico indicated that the proportion of school-age children and adolescents who eat fish, fruits and vegetables, is low, while those who routinely consumed energy-dense foods and low nutrient density foods such as soft drinks, sweets, salted snacks and shortbreads, is high (Ortiz y Ramos, 2008). Therefore the coexistence of obesity and malnutrition, has introduced a previously atypical situation which, in turns, produces a double disadvantage (Sánchez-Castillo, Pichardo-Ontiveros y López-R, 2004).

In the past 50 years there have been several nutrition and childhood studies published that have clearly showed the negative impact of malnutrition on cognition, behavior, and physical performance (Fanjiang y Keinman, 2007). Walker et al., (2005), found that the effects of malnutrition on educational and cognitive activities in children during early childhood, continues into late adolescence. García, Padrón, Ortiz-Hernández, Camacho y Vargas (2005) found that malnutritioned Mexican children between the 3rd and 4th year of elementary school were found to have low birth weight and low height for their age, which are signs of malnutrition, and they were more likely to repeat school years. Similar results were found in a study that investigated the relationship between nutritional status and IQ showing that a nutritional deficiency leads to a lower intellectual level in both obese and malnutritioned children, this study was conducted with 203 Mexican children between 6 and

13 years (Navarro-Hernández y Navarro-Jiménez, 2002). When food insufficiency was used rather than malnutrition results showed that children between 6 to 11 years had a significant decrease in mathematical, reading, cube design and working memory abilities compared to a control group (Alaimo, Olson y Frongillo, 2001).

Obesity is also believed to be associated with cognitive deficits, but the research is inconclusive and methodologically problematic (Taras y Potts-Datema, 2005). For example, studies have found that higher body mass index (BMI) is associated with poor cognitive function in children (Wang y Veugelers, 2008). However, in another study Gunstad et al., (2008) reported no relationship between high BMI and cognitive dysfunction in healthy children. Also a longitudinal study reported no association between weight and verbal intelligence (Richards, Hardy, Kuh y Wadsworth, 2002). Cserjési, Ceresin, Molnár, Luminet y Lénárad (2007), reported no differences in working memory and abstract reasoning (measured with arrays) or semantic verbal function and Verdejo-García et al. (2010) reported no differences in decision making process. In contrast, other studies found an association between obesity and decreased academic performance in children, affecting girls more than boys (Mond, Stich, Hay, Kraemer y Baune, 2007). In general, obesity has been linked with decreased academic performance.

However, no direct comparisons between obese and malnutrition of children had been conducted so far, in terms of intellectual or academic performance, to compare the relevance of former deficits in such a nutritional problems. To know the type and frequency of intellectual and academic potential differences could be important to establish specific resources in order to support these children. As mentioned, research findings on this topic have been inconclusive (Taras y Potts-Datema, 2005), the lack of appropriate and standard measurement of suspected deficits has been cause of such findings (Wachs, 2000). In essence, whereas there is a clinical evidence to suggest a link between maladaptive eating patterns during childhood and subsequent cognitive deficits according to the literature as it presently stands is inconclusive, at best, is problematic, at worst.

Therefore, the purpose of this study was to investigate how malnutrition and obesity affect both fluid intelligence and academic performance of Spanish speaking children between 8 to 9 years of age. Of additional interest is the use of such tests while controlling variables such as socioeconomic status, culture, and intelligence of the mothers as these variables may modulate the potential effect associated with the presence of both malnutrition and obesity. It was hypothesized that malnutrition and obesity are linked with low cognitive and academic performance.

4.2 Method

This study was conducted in two schools in Ciudad Juarez, in the state of Chihuahua in Mexico. A total of 98 children between 8 to 9 years old (*M*= 8.38, SD= 0.49), (46 boys and 52 girls) who were enrolled in the third or fourth grade were recruited. Of the sample, 35 children were malnutritioned (MG), 31 were in normal nutritional status (control group) (NNG) and 32 were obese (OG).

The socioeconomic status (SES) of the participants in the sample was low, and all resided in urban locales. Participants were recruited from a low socio-economic area of Ciudad Juarez, Mexico. SES was based on the II Conteo de Población y Vivienda, (2005) based on data such illiteracy, number of individuals living per room, etc. The criteria used was as follows; 1. Very low SES. 2. Low SES. 3. Mid SES 4. High SES 5.Very high SES. According to the Plan de Desarrollo Urbano (2010) of the Ciudad Juarez, the two neighborhoods used for the study residents are of the Low SES group. Exclusion criteria were the history and/or presence of neurological diseases (e.g., epilepsy, traumatic brain injury, or other neurological syndromes) and hormonal diseases (diabetes or thyroid-related diseases). The demographics and clinical characteristics of the sample can be seen in Table 1.

The children's parents were fully informed of the study prior to their participation and, if agreed, their consent was obtained. This project, including the informed consent, was approved by the bioethics committee of the Autonomous University of Ciudad Juarez (UACJ).

4.3 Materials

4.3.1 Anthropometrics Measurements

Core measures were identified (weight and height) and anthropometric index taken (McLaren index, percentages of weight/age height/age and weight/height). The anthropometric measurements were obtained according to the specifications manual of anthropometry of the National Council for Science and Technology (CONACYT) (Aparicio, Estrada, Fernández y Hernández, 2004).

The weight was determined by a Seca ® electronic scale. The size was measured in a standing position, with the head placed so that the plan of Frankfurt was at the horizontal position, a Harpenden stadimeter was used to get these measurements. All participants were wearing school uniforms (skirt and shirt for girls and pants and shirt for boys) and no shoes during the anthropometric data collection phase. The reference standards for weight and height were the curves and growth tables of the Center for Diseases Control (CDC) (2009) in 2000. For the classification of nutritional status cut-off points were used in the standings from McLaren y Read (1975) and Waterlow (1972).

4.3.2 Cognitive Measures

Measures used with the children. Factor "G" of Catell (2001), was administered. This test measure fluid intelligence and is divided into 4 tasks (Series, Classification, Progressive Matrices and Topological Conditions). The total scores are converted into IQ scores.

4.3.3 Academic abilities

Measures used with the children. Scholars Aptitude Test (TEA-1) (Thurstone and Thurstone, 2004) was administered. This test has 5 subtests (drawings, different word, vocabulary, reasoning and calculus) which evaluate three aptitude dimensions: verbal, reasoning and calculation, which can produce an IQ score.

Measures used with the mothers. The Beta III (Kellogg and Morton, 2003) was administered to the mothers after completion of informed consent. This test measures non verbal intelligence, processing information, processing speed, spatial reasoning, non verbal reasoning and aspects of fluid intelligence. This test has 6 subtest (figure completion, digits, associated pairs, object assembly, and matrices).The subtests then provides a composite IQ.

4.4 Procedure

Two schools from a low socio-economic area of Ciudad Juarez participated in the project. A meeting was held and parents were informed about the project. An informed consent was given to the parents that showed interested in participating in the study. The mothers then completed the Beta III (Kellogg and Morton, 2003) intelligence test as well as completed a demographic questionnaire about their children. During the following days the children anthropometric measurements were taken to determine their nutritional conditions.

Once the sample classification based on their nutrition was obtained, the two IQ tests and TEA-1 tests were given in groups of 10 in morning during school hours. The test was administered by three trained psychometricians (one professional and two students in their last semester of psychology training) in the two selected school.

4.5 Variables and statistical analysis

The grouping variable or independent was the nutritional status which was divided into three groups: obese (OG), normal nutrition (NNG) and malnourished (MG). The cut off points MG was 85-95% in height/age and 70-90% in weight/age, for the NNG was 95-105% and 90-110% respectively and for OG was up 120% in both (Waterlow, 1972).

The dependent variables to measure the IQ scores were used directly for the four subscales of Factor G:

Series (Se): Score direct series subtest.

Classification (Cl): Score direct classification subtest.

Progressive Matrices (PM): Score direct t matrices subtest.

Topological Conditions (TC): Score direct subtest topological conditions.

Total Direct Score (Tot DS). The sum of the direct scoring of the four subscales: series, classification, progressive matrices and topological conditions.

The direct test scores were used as the academic performance variables. The following are the tests used:

Drawings (Dw) directly in the subtest scores of drawings.

Different words (Dif Word): direct score in the subtest of different words.

Vocabulary (Voc): direct score in the vocabulary subtest.

Reasoning (Ra): Direct score reasoning subtest.

Calculus (Ca) directly in the subtest score calculation.

Total Verbal (Tot Ver): sum of scores on the subtest direct designs, different words and vocabulary.

Total Non-verbal direct (Tot NV): sum of the scores in the subtest of reasoning and drawings. Total Global (Tot G): Total of scores in the subtest direct designs, different words, vocabulary, reasoning and calculation.

Intellectual Coefficient (IQ): The global intellectual coefficient.

In order to study the differences among the groups, a multivariate analysis of variance (MANOVA) was done using a diagnostic group as the independent variable (OG vs. NNG vs. MG). The scores on the psychological tests were used as dependent variable. An ANOVA was conducted. Post hoc comparisons and Scheffe test were conducted after the ANOVA. Statistical associations among variables were studied using the Pearson Correlation Test.

4.6 Results

Groups were equally distributed according to the demographic variables of the children and their mothers. Results showed that there was no statistically significant difference in the age of the children; IQ, academic level or economic status of the mothers. However, differences were found in the percentage of boys and girls in each group, which is congruent with the prevalence differences of these disorders between boys and girls (Olaiz et al., 2006) (see Table 1).

Table1. Socio-demographic characteristics of the participants.

Socio-demographic Characteristic	MG	NNG	OG	F / Chi	*p*

Age of Mother (Mean / SD)	32.03(4.74)	32.51(5.94)	30.03 (2.44)	2.385	0.098
Mother's Educational Attainment % (n):				0.800	0.452
Elementary School	11.8 (4)	6.5 (2)	10.3 (3)		
Secondary School	24.4 (10)	33 (10)	37.9 (11)		
High School completed	47 (16)	38.8 (12)	34.5 (10)		
Technical degree	5.9 (2)	9.7 (3)	17.2 (5)		
Bachelors degree	5.9 (2)	12.9 (4)	0 (0)		
Mother's IQ(Mean/SD)	86.69(9.97)	86.12(8.28)	85.86(6.62)	0.079	0.924
Child's Gender (%)				3.384	0.038
Female	68.6	51.6	37.5		
Male	31.4	48.4	62.5		
Total	35.7	31.6	32.7		
Child's Age (Mean/SD)	8.54(0.50)	8.25(0.44)	8.37(0.49)	2.975	0.06
Social-economic status (%)					
Low	100	100	100		
Academic performance	7.9 (0.88)	8.2 (0.66)	8.6 (0.88)		
Scholar absenteeism	2.82 (3.44)	0.66 (0.83)	0.87 (1.45)		
Physical activity performed (at least one hour per week) (%)	100	100	100		

Note: SD=Standar Desviation

In order to evaluate if the gender variable affects the IQ measures and academic performance, an ANOVA analysis was performed and results showed that there were no significant difference between boys and girls regarding IQ and academic performance. Therefore, gender was not considered in the next analysis.

A, possible differences between groups in IQ scores was pursued. The results showed that there were significant differences for the four Factor G subtests [Lambda (8,184) = 0.812, p<=0.012]. Further univariate ANOVAS showed that the PM subtest [F (2,95) = 5,503, p <0.005], TC [F (2, 95) = 3'194, P <0.005], and Tot DS [F (2, 95) = 4'070, P <0.005], in the obese group was significantly lower than the OG and MG (see Table 2).

Table 2. ANOVA for IQ of three groups of children

Variable	MG M (SD)	NNG M (SD)	OG M (SD)	F	*p*	Post Hoc
Se	3.82 (2.66)	4.19 (1.86)	3.15 (2.60)	1.49	0.229	_
Cl	3.94 (1.92)	4.96 (2.15)	4.43 (2.22)	1.95	0.147	_
PM	4.45 (2.61)	4.61 (2.01)	1.96 (1.82)	5.5	0.005	(MG=NNG)>OG
TC	2.80 (1.49)	3.06 (1.93)	2.09 (1.27)	3.19	0.045	(MG=NNG)>OG
Tot DS	15.02 (6.89)	16.83 (5.79)	12.65 (4.45)	4.07	0.02	(MG=NNG)>OG

Note: M= Mean, SD= Standard Deviation, Se= Series, Cl= Classification, PM= Progressive Matrices, CT= Topological Conditions, Tot DP= Total Direct Score.

Possible differences between groups in academic performance scores were then explored. The results showed that significant differences existed for the Dw subtest [F (2,95) = 4,526, P <0.013], with the obese group being significantly lower than MG and NNG (See Table 3).

Table 3. ANOVA for three groups of academic performance

Variable	MG M (DT)	NNG M (DT)	OG M (DT)	F	ρ	Post Hoc
Dw	9.82 (1.27)	9.80 (1.13)	8.87 (1.86)	4.52	0.013	(MG=NNG)>OG
Dif Word	5.45 (2.54)	6.32 (1.73)	6.25 (2.85)	1.3	0.275	_
Voc	6.14 (2.92)	6.35 (2.24)	6.09 (2.38)	0.09	0.911	_
Ra	14.25 (4.38)	14.64 (5.43)	14.03(4.86)	0.12	0.881	
Cal	12.71 (6.18)	14.51 (5.03)	12.09 (4.92)	1.68	0.191	_
Tot G	47.94 (12.75)	51.64 (10.97)	47.34 (12.16)	1.18	0.31	_

Note: M= Mean, SD= Standard Deviation, Dw=Drawings, Dif Word=Different Words, Voc=Vocabulary, Ra=Reasoning, Cal=Calculus.

Finally, the relationship between IQ scores of each group and academic abilities was considered. Results showed moderately high direct correlations of the subtests Progressive Matrices, Topological Conditions and overall G-factor scales with academic abilities performance in the three groups (See Table 4).

Table 4. Relation between IQ and academic performance

Total Direct Score (Factor G)			
Variable	MG	NNG	OG
DW	0.463**		0.472**
Voc		0.655**	0.585**
Ra	0.570**	0.645**	0.413*
Cal	0.603**		0.539**
Tot. Ver	0.360*	0.629**	0.673**
Tot. NV	0.571**	0.659**	0.510**
Tot G	0.662**	0.672**	0.650**

***=p<0.01; *= p<0.05*

4.7 Discussion

The purpose of this study was to compare intellectual abilities and academic performance of Spanish speaking obese and malnourished children, between 8 to 9 years. The results showed that obese children had lower performance in fluid intelligence and nonverbal academic skills than mild to moderate malnourished children. Also, moderately high direct correlations of the progressive matrices subtest with academic skills have been found.

Our results showed that obesity affect the intellectual and academic skills more than mild to moderate malnourishment. In fact, latter condition showed the same performance than the control group. According with these results, obese children could require more support during scholarship. On the other hand, no significant differences were found in the IQ of the mothers, years of schooling, and age of the mothers. As children of the same area and lower-middle socioeconomic status the differences found in IQ cannot be explained by socioeconomic status. The only similar study was carried out by Navarro-Hernández and Navarro-Jiménez (2002), the results of this study are consistent with the present study in that they support the hypothesis that nutritional alterations are associated with decreased intellectual performance, but the Navarro-Hernández and Navarro-Jiménez (2002) study used only an infrequently used and somewhat subjective IQ test, the Goodenough.

The present study supports previous studies that investigated obesity and malnourishment in children (Cserjési et al., 2007). In contrast with Gunstad et al. (2008), the present study did find significant differences between obese and control groups, in fluid intelligence, specifically in Progressive Matrices and Topological Conditions. Nevertheless no differences in verbal abilities were found, as previously mentioned by Richards et al. (2002).

Some prior studies found that obesity is associated with a decreased academic performance in children, particularly in girls (Mond et al., 2007) whereas, Azurmendi et al. (2005), did not find differences between gender. The present studies are supportive of Zlotkin (2006) and Caballero (2005) in that obesity and malnutrition in children of low socioeconomic status may be associated with the particular characteristics of Ciudad Juarez. Specifically border cities in Mexico are fraught with poverty, crime and unstable socio-economic circumstances. (Ortiz and Ramos, 2008; Zlotkin, 2006).

Some limitations of the present study should be considered. The three major ones include 1) only a limited range of socioeconomic standards were included. 2) Severe malnourished states were not included. 3) Finally, the length of the nutritional status of the participants is not known. Replications of these findings in other Spanish speaking countries, or other non-English speaking developing countries may allow for greater generalizability of the relationship of previously published studies.

In summary, IQ was related to the academic performance of the children and such cognitive performance was linked to obesity more than malnutrition. This is congruent with previous studies that have found such a relationship (Foley, García, Shaw and Golden, 2009) but it extends previous findings by controlling important variables such as mother's intelligence and children's socio-economic status. However, despite these findings further study attempting to understand how malnutrition and obesity, combined and alone, affect subsequent cognitive functioning is cleared needed.

Capítulo 5 Malnutrition and Executive Functions in Spanish-speaking Children

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5.1 Introduction

Recently, the role of neuropsychology in the school has been emphasized due to the growing neuropsychological evidence of numerous learning and behavioral disorders, and to recent developments supporting neuropsychological testing in schools (Clearly and Scott, 2011). A number of medical influences, including neurological conditions (i.e., infants with low birth weight, children with head injuries), mental health problems (i.e., behavioral and social-emotional problems, attention deficit disorder and hyperactivity disorder), and altered nutritional conditions (i.e., malnutrition, obesity), are driving the interest in school neuropsychology (Clearly and Scott, 2011).

Malnutrition is also an important issue in education, because it affects cognitive development and academic performance. Researchers have exhaustively reviewed published studies about nutrition among school-age children and have shown that school feeding can help improve academic performance and cognitive functioning among children, particularly malnourished children (Hoyland, Dye and Lawton 2011; Grantham-McGregor, 2005; Taras, 2005).

However, most of the cognition and malnutrition studies focus on pregnancy and infancy (Fanjiang and Kleinman, 2007; Walker et al., 2005). Few studies have focused on the later ages of children (Benton, 2008). Although most of these studies are not recent, it has been found that stunting (as a measure of malnutrition) at an early age negatively affects non-verbal intelligence at later ages (Mendez and Adair, 1999). Likewise, a study has shown that children who were severely malnourished during their first year of age had lower scores on the WAIS test, on Raven´s Progressive Matrices, and in academic performance at the end of high school (Ivanovic et al., 2000).

In particular, an important brain function that has been found to be affected in malnourished children is executive function (EF) (Kar, Rao and Chandramouli, 2008), although it is difficult to measure at early ages (Koren, Kofman and Berger, 2005) because it develops with age. In a recent study undertaken in India, children between the ages of 5 and 10 with protein-energy stunting (as a measure of malnutrition) showed a lower performance in EF compared with normally nourished children (Kar, Rao and Chandramouli, 2008). Specifically, the study found that malnourished children had poorer performance in working memory tests, particularly in phonetic fluency, than did normally nourished children. There is no more research linking EF with malnourished children.

In the above-mentioned study, the authors found differences in EF depending on the age of the children; the age group consisting of children from 8 to 10 years old had better performance in phonetic fluency tests compared with the group of children from 5 to 7 years of age. In the same test, however, children from 8 to 9 years old showed no significant differences from the children of 10 to 11 years of age (Koren, Kofman and Berger, 2005). Some researchers agree that children from 8 to 11 years old obtain scores from 11 to 15 words in semantic fluency and from 6 to 8 words in phonetic fluency, and children do not reach adult maturity levels until the age of 12 years (Koren, Kofman and Berger, 2005). Another recent study found that 8-year-old children made more mistakes due to lack of attention, impulsivity, and distractions compared with 10 to 12 year-old children (Klimkeit, Mattingley, Sheppard, Farrow and Bradshaw, 2004). This study did not consider the academic performance of participants. Only a few studies have examined the relationship between malnutrition and academic achievement in older children, and have found associations between malnutrition and lower academic performance (Themane, Monyeki, Nthangeni, Kemper and Twisk, 2004). In this type of studies, however, neurocognitive measures such as executive function have not been considered.

There are few studies on cognitive performance in malnourished children of 8 to 12 years of age, especially when measuring EF and academic performance. Indeed, most studies on EF have been based on attention deficit disorder and hyperactivity disorder, autism, schizophrenia, depression, or traumatic brain injury (Dennis, Agostino, Roncadin and Levin, 2009; Nyberg, Brocki, Tillman and Bohlin, 2009). However, the evidence points to the likelihood that malnutrition is associated with impaired cognitive abilities in later life.

The aim of this study was to investigate how malnutrition affects EF and academic achievement in children of 8 to 12 years of age. We hypothesized that malnourished children have impaired executive skills and will have worse performance on executive tasks and academic performance compared with normally nourished children.

5.2 Methods

5.2.1 Subjects

The study was conducted in two schools in Ciudad Juarez, located in Chihuahua State, Mexico. A total of 78 children in the age group of 8 to 12 years (32 boys and 46 girls; *M*= 9.18, SD= 1.046) participated in the study. The students were enrolled in the third, fourth, fifth, and sixth grades. Out of the sample, 52 children were malnourished (MG) and 26 were with normal nutrition (NNG). The socioeconomic status (SES) of subjects in the sample was low, living in an urban area. Exclusion criteria included any pre-existing neurological disease (e.g., brain injuries, epilepsy, and degenerative syndromes) and hormonal diseases (e.g., diabetes or thyroid-related diseases). Table 1 shows the socio-demographic and clinical characteristics.

The children's parents were informed about the study and, if they allowed their children to participate, their consent was obtained. The study was also approved by the Bioethics Committee of the Autonomous University of Ciudad Juarez (UACJ).

5.2.3 Material

Anthropometric Measurements. The anthropometric measurements were identified as core measures (weight and height) and anthropometric indices (McLaren index, percentages of weight/age, height/age, and weight/height). The anthropometric measurements were performed according to the specifications of the anthropometry manual of the National Council for Science and Technology (CONACYT, 2005). Weight was determined by a Seca® electronic scale. Size was measured with the subject in a standing position, with the head placed so that the plan of Frankfurt was at the horizontal position; a Harpenden stadimeter was used to get these measurements. All subjects wore light clothing (i.e., blouse, skirts, and undergarments for girls; shirt, trousers, and undergarments for boys) and no shoes during the anthropometric data collection phase. The reference standards for weight and height were the curves and growth tables taken from the National Center for Health Statistics (NCHS) in collaboration with the National Centers for Chronic Disease Prevention and Health Promotion in 2000.

Executive Function Measures. EF measures were obtained using several different measures. EF was divided into three basic components: updating, inhibition, and shifting (Verdejo-García and Pérez-García, 2007; Fisk and Sharp, 2004).

1. - Inhibition Measurements:

- The Spanish children's version of the Stroop Color and Word Test (Golden, 2005). The test contains three lists. Children have to read words in the first list, say the name of colors in the second list, and say the name and color of the printed words as quickly and as accurately as possible in 45 seconds per task in third list.

- The go/no-go task (Perales, 2003 cited by Verdejo-García, Bechara, Recknor, Pérez-García, 2007). The task consists of 100 trials (50 go and 50 no-go). The individual is asked to press a computer key as quickly as possible if a go stimulus appears and not to press the key if the no-go stimulus shows (this part was a preswitch). During the next part of the test (postswitch) when a sound is heard, the task is inverted: the go stimulus is now the no-go stimulus, and vice versa. The go and no-go stimuli are represented by a dolphin and a bear, respectively. Every time the subject gives an answer a sound feedback (one of two) is given telling the subject if the answer was correct or incorrect. The inter-stimulus interval (ISI) was set at 100 ms, and each stimulus was presented for 1000 ms. The main dependent variables from this test were hit and false-alarm rates. These variables were analyzed across 10 blocks of 10 trials to explore the effects of learning and switching during the task.

2. Updating Measurements:

- Letter-number sequencing. This subtest of the WISC-IV (Spanish version) (Wechsler, 2007) consists of giving the subject a mixed set of numbers and letters orally, with the subject having to complete two tasks. First, the subject has to arrange the numbers in ascending order orally and then arrange the letters in alphabetical order orally from the previously given set.

- Matrix reasoning (Wechsler, 2007). The goal is to complete the picture matrix with any of the given solutions.

- Phonetic verbal fluency (Matute, Rosselli, Ardila and Ostrosky-Solís, 2007). Subjects are asked to say all the words they can recall beginning with the sound “m” in a one-minute period. The task excludes proper nouns, repeated words, or derived words in Spanish, such as “muñeca” and “muñequita”.

- Semantic fluency (fruit and animals) (Matute et al, 2007). Subjects are asked to say all the names of animals or fruits that they can remember in a one-minute period. The task excludes repeated words, or referrals as “pollo” and “pollito”.

3.- Shifting measures:

- Trail-making test (Reitan, 1958). This test has two parts, A and B. The participant in part A must join with lines the numbered circles in a consecutive form. In part B, the participant must join the circles with numbers and letters consecutively.

4. Academic performance:

- Academic performance was the average of the ratings that the children had in the subjects of Spanish, Mathematics, History, Geography, and Science.

5. Absenteeism:

- Absenteeism consisted of the times the child did not go to school in the two months before the study was conducted.

5.3 Procedure

Students were recruited from two schools in the low socioeconomic area of Ciudad Juarez, Mexico. SES was based on the II Conteo de Poblacion y Vivienda (2005) data covering such areas as illiteracy, number of individuals living per room, etc., which are the foundation of an SES system. SES was classified as follows: 1, very low SES; 2, low SES; 3, middle SES; 4, high SES; 5, very high SES. According to the Plan de Desarrollo Urbano (2010) of Ciudad Juarez, the residents of the two neighborhoods used for the study are of the low-SES group. A public meeting was held and parents were informed about the project. An informed consent form was provided to the parents who showed interest in participating in the study. The mothers then completed the Beta III (Kellogg and Morton, 2003) to assess their IQ. In addition, a demographic questionnaire was administered to the parents to obtain data about the children's development and disease history. During the following days anthropometric measurements were taken to determine the nutritional status of the participating children. Malnourished children were defined as those who had less than 90% of the expected weight conforming to age and height, considering the percentile 50 value of the NHCS standards as the expected weight. Tests were then administered individually to the children in an isolated room during school hours by a trained technician.

5.4 Data Analysis

The independent variable was nutritional status (NS), which was divided into two groups: normal nutrition (NNG) and malnourished (MG). The ages of the children were divided into two groups: 8 years and 9 to 12 years. The dependent variables were the scores obtained on each EF test, and each of academic performance scores:

- Letter and number sequence (L&N): direct score in the letter and number sequence test:
- Matrix reasoning (MR): direct score in the matrix test;
- Stroop Word (SW): direct score in Stroop Word;
- Stroop Color (SC): direct score in Stroop Color;
- Stroop Color-Word (SCW): direct score in Stroop Color-Word;
- Go/No-go hits (Go-H): rate of hit;
- Go/No-go hits (Go-FA): rate of false-alarm;
- Trail-making test (TMT): direct score in the trail-making test;
- Absenteeism: total absenteeism in the bimester;
- Academic performance: the average of the ratings that the children had in the subjects of Spanish, Mathematics, History, Geography, and Science.

To analyze the differences in socio-demographic variables, ANOVA Chi-Square across tables was conducted according to the variables. The differences between groups (NNG vs. MG) and age (8 vs. 9 years old) were analyzed using bifactorial MANOVA (two or more dependent variables in the neuropsychological test) or ANOVA (one dependent variable).

5.5 Results

First, ANOVA and Chi-square analysis of socio-demographic differences revealed no significant differences in any of the variables between NNG and MG (see Table 1).

Table 1 Sociodemographics Characteristics of the participants

	MG	*NNG*
Age of Mother (Mean / SD)	32.42 (4.55)	33.92 (5.83)
Mother's Education (%):		
Elementary school	7.7	7.7
Elementary school not completed	0	3.8
Secondary	28.8	23.1
Secondary not completed	3.8	11.5
High School	34.6	19.2
High School not completed	3.8	3.8
Technical degree	11.5	19.2
Bachelors degree	3.8	11.5
Mother's IQ (Mean/SD)	85.33 (9.47)	84.19 (10.96)
Child Gender:		
Female	59.6	57.7
Male	40.4	42.3
Total	59	41
Child age (Mean/SD	9.25 (1.10)	9.05 (0.92)
Social-economic status (%)		
Medium - Low	*100*	*100*
Academic performance	7.91 (0.90)	8.5 (0.87)
Scholar absenteeism	2.09 (2.70)	1.23 (2.08)
Physical activity performed (at least one hour per week) (%)	100	100

Executive function differences between the groups

In the updating component, the results of MANOVA showed significant differences among age groups in L&N, F (1,74) = 7.49, *p*<0.008, and in MR, F (1,74) = 0.410, *p*<0.046, with children older than 9 years of age showing better performance compared with children 8 years of age. Significant differences were found in the fluency task for all three conditions, Lambda (1, 74) = 0.249, *p*<0.000 and such differences depended on age, Lambda (1, 74) = 0.838, *p*<0.002. Moreover, children 8 years of age showed worse performance than children 9-12 years of age in the animals condition, F = 20.599, *p*<0.000 (see Table 2).

In the inhibition component, however, when the NS and the age group variables were considered, significant differences were found for the go/no-go task, in Go-FA conditions [Lamda (9,64) = 0.743; *p*<0.018] and Go-H [F (Sphericity assumed) (1,72) = 2.065; *p*<0.031] reflected in the 9-12 year-old MG, which showed lower performance compared with the 9-year-old NNG. Go-FA and Go-H rates were then computed for each of the 10 phases (see Table 3). There were no significant phases in Go-FA at 8 years, but blocks 3 (F= 13. 112, *p*<.001,) 8 (F= 5.111, *p*<.029), and 9 (F = 8.296, *p*<.006) at 9 years were significant. In Go-H at 8 years, blocks 1 (F = 14. 767, *p*<.001), 8 (F = 12.123, *p*<.002), and 9 (F =10.154, *p*<.003) were significant; at 9 years, blocks 3 (F= 7.574, *p*<.008), 6 (F = 7.335, *p*<.010), and 10 (F= 19.810, *p*<.000) were significant, with malnourished 9-12year-old children having worse performance for both rates compared with the 9 years and older NNG.

In the Stroop test, all three conditions showed differences between age groups [Lambda (3.72) = 0.796; p<0.001]. The subsequent univariate results showed that the two age groups were significantly different for the conditions SW [F (1, 74) =7.831; *p*<0.007], SC [F (1, 74) = 18.23; *p*< 0.000] and SCW [F (1, 74) =7.090; *p*<0.010], reflecting the lower performance of the younger age group (see Table 2).

Table 2. MANOVAS and ANOVAS of the function executive measuerements

Domine	Variable	MG(M and SD)		NNG (M and SD)		Main effects / Interactions	F/ Lambda	Significance	Univariate Contrasts	
		8 years	9 to 12 years	8 years	9 to 12 years				F	ρ
Updating	L&N	8.59 (5.04)	10.50 (5.05)	6.90 (5.43)	12.20 (6.51)	Age	7.49	0.008	N/A	N/A
	Animals	7.68 (2.91)	11.43 (2.88)	9.00 (2.64)	10.93 (3.69)				20.559	0
	Fruit	7.77 (1.57)	8.56 (2.23)	8.72 (2.00)	8.06 (2.34)	Fluency	0.249	0.000	0.427	0.515
	"m" Sound	4.40 (2.08)	5.56 (2.76)	3.63 (1.85)	4.40 (2.89)	Fluency*Age	0.838	0.002	3.156	0.08
	MR	11.68 (3.53)	12.46 (4.04)	12.00 (3.54)	15.00 (4.03)	Age	4.1	0.046	N/A	N/A
	SW	55.40 (12.03)	60.86 (16.51)	47.09 (16.99)	61.66 (12.53)				0.007	7.831
Inhibition	SC	38.68 (7.10)	48.06 (10.09)	37.36 (4.58)	44.73 (6.49)				0	18.233
	SCW	20.72 (4.14)	24.30 (5.51)	21.36 (4.20)	24.86 (7.52)	Stroop	0.796	0.001	0.01	7.09
	Go-FA*					Go-no-go*	0.743	0.018		
	Go-H*					age*Group	2.065	0.031		
Shifiting	TMT A	108.90 (74.33)	25.34 (36.19)	96.75 (19.27)	67.17 (44.71)	TMT	0.653	0	28.195	0
	TMT B	168.86 (135.80	43.94 (76.42)	214.64 (151.04	151.72 (98.42)	TMT*Group	0.906	0.012	12.192	0.001

Note: * Results on the go-no go by blocks are shown; M= Mean; SD= Standard Deviation; L&N= Letter and Number Sequence; MR= Matrix Reasoning; S.W= Stroop Word; S.C:= Stroop Colors; S.C.W =Stroop Color-Word; GO-FA= Go/no-Go False alarm; Go-H=Go/no-Go Hits; N/A = Not applicable.

Finally, similar results were found for the flexibility component. In TMT the two conditions of MANOVA showed significant differences between the age groups [Lambda (1, 65) = 0.653; $p<0.000$]. These differences depended on age [Lambda (1,65)= 0.906; $p<0.012$], with the performance of 8-year-old children being below that of children 9 years of age or older in both conditions TMT-A (F = 28.195; $p<0.000$) and TMT-B (F = 12.192; $p<0.001$) (see Table 2).

Academic performance, absenteeism nutritional condition, and executive functioning

We examined whether the MG and NNG differed in academic performance and absenteeism. The results showed that malnourished children had significantly lower academic achievement (NNG=8 vs. MG=7) [t(1,76)= -2.649; $p< 0.010$] but the same statistical absenteeism (NNG=1.3 vs. MG=2.09).

To explore if neuropsychological performance was related to academic performance and nutritional status, Pearson correlations were conducted between academic achievement and the EF variables separately for each group. The results showed that abstract reasoning, working memory, and resistance to interference in the Stroop among malnourished children were positively related to better grades. In the group of healthy children no relationship was obtained (see Table 3).

On the other hand, in the case of absenteeism, verbal fluency (fruits) and working memory were inversely related in MG, and the measures of processing speed (Stroop color and time of TMT-A) in NNG (see Table 3).

5.6 Discussion

The main objective of this research was to study malnutrition and EF in Spanish-speaking children. The results indicate that the MG showed worse execution in the impulsivity task (go/no-go), but this depended on the age of the children (only in the 9-12 years age group). Our results also showed that executive functions are related to academic performance and absenteeism in the malnourished group but not among healthy children.

Table 3. Pearson correlation between academic performance, absenteeism and executive functions.

Domain	Variables	*MG*		*NNG*	
		Academic performance	Absenteeism	Academic performance	Absenteeism
Updating	L&N	0.273*	-0.301*		
	Animals				
	Fruit		-0.449**		
	“m” sound				
	MR	0.368*			
Inhibition	SW				
	SC				-.0470*
	SCW	0.303*			
	Go-FA				
	Go-H				
Shifting	TMT-A				0.436*
	TMT-B				

Note: **=p<0.01; *= p<0.05. L&N= Letter and Number Series; MR= Matrix Reasoning; SW= Stroop Word; SC= Stroop Colors; SCW= Stroop Color-Word; Go-FA= Go/no-Go False alarm; Go-H= Go/no-Go Hits; TMT A= Trail Making Test A; Trail Making Test B.

It is important to point out that the EF abilities can be measured starting at the age of 7 (Best, Miller and Jones, 2009; Schachar and Logan, 1990). The lack of significance at the age of 8 may be due to incomplete frontal maturation instead of other factors such as malnutrition. Further, performance on EF measures does improve with development (Huizinga, Dolan and van der Molen, 2006; Nigg, Quamma, Greenberg and Kusche, 1999; Williams, Ponesse, Schachar, Logan and Tannock, 1999). The results show that at the age of 9 years, the MG does not reach the development level of the NNG. One of the aspects measured by the go/no-go task is motor impulsivity, which is a reliable indicator of impulsive behavior (Dougherty et al., 2003). Hence, a salient explanation may be impulsivity or, alternatively, disinhibition.

In contrast, in the age variable, the present results support the findings of Williams et al. (1999) who also found that in the Stroop signal task (an inhibition task like go/no-go) 9- to 12-year-old children responded better than did 8-year-olds. In the Stroop test our results showed that 8-year-old children have lower performance than children 9 years of age and older. Children less than 8 years of age do not appear able to answer correctly (Williams et al., 1999). They improve their performance at 9 years of age, reaching the maximum performance when they reach adolescence or at later ages (Crone, 2009). In fluency, the results showed significant differences by age group, with the group of 9-year-olds showing improved performance in the animal's category. An explanation for this is that animals are a natural category, which is one of the first types of narrative categories to be mastered. Scores on animal fluency continue improving until the age of 12 years, whereas scores on fruits continue to increase until the age of 12 to 15 years (Valencia et al., 2000). Further, the present results are consistent with Brocki and Bohlin (2004) and with Kar, Rao and Chandramouli (2008), who found that developmental differences depend on the EF component measured. In general we agree with Kalkut, Han, Lassing, Holdnack, and Delis (2009) in the sense that the performance of EF tasks improves with age.

Our results also show a relation between academic performance, absenteeism, and EF measures in the malnourished group but not in the healthy one. These results are consistent with a previous paper that found low cognitive and academic performance in malnourished children. However, we found a differential relationship for academic achievement and absenteeism: the former is related to updating and inhibition measures and the latter to flexibility. This enhances the importance of measuring EF in malnourished children.

Limitation

It is important to highlight that the present sample was socioeconomically homogenous. In addition, severely malnourished children were not included in the study and could play a significant role in helping to explain a more complex picture of the relationship between malnutrition and neuropsychological functioning.

Implications for schools

These results do point to a strong association between malnutrition, executive dysfunction, and academic performance. It is necessary to emphasize the importance of adequate nutrition for students, because the bad consequences of malnutrition can be observed from school age. Preventing malnutrition in school in underdeveloped countries is essential for good academic performance by children and later by adults. Toward this end it is necessary to create programs that teach proper nutrition in childhood.

Capítulo 6. Psicopatologías en niños desnutridos medidas con el CBCL/6-1*8*

Verónica Portillo-Reyes, Miguel Pérez-García, Antonio Puente y Yolanda Loya-Méndez (2011). Psicopatologías en niños obesos y desnutridos medidas con el CBCL/6-18. *Actas Españolas de Psiquiatría,* artículo en revisión.

6.1 Introducción

La desnutrición es un problema alimenticio que afecta a la salud pública, particularmente, a los países en vías de desarrollo especialmente durante la niñez. Datos del 2008 proporcionados por la UNICEF (2008), afirman que México ocupa el lugar 22 de entre los primeros 24 países con el mayor número de niños menores de 5 años con desnutrición y el único de ellos, que no se encuentra en África o en Asia.

Las cifras son alarmantes debido a las repercusiones que tiene este problema. Por ejemplo, la desnutrición contribuye a aumentar los gastos en la atención de la salud pública (McLachlan, 2006). A nivel individual, disminuye la productividad (McLachlan, 2006) y el rendimiento físico y cognitivo (Fanjiang G y Kleinman, 2007). Además, los niños desnutridos tienen más riesgo de padecer enfermedades infecciosas como lo son: la malaria, la diarrea, el sarampión y la neumonía (Caulfield et al., 2004).

Por otro lado, el desarrollo de trastornos psicopatológicos durante la niñez ha sido estudiado por diversos autores, sin embargo existen escasos estudios sobre la asociación entre estos la desnutrición (Oddy et al., 2009). Además la relación adversa que guardan con este estado nutricio es poco definida (Liu, Raine, Venable y Sarnoff, 2004). En uno de los trabajos que trata sobre la dieta y psicopatologías en adolescentes, se evidencia la asociación entre una salud mental más pobre y la dieta occidental, la cual se caracteriza por un mayor consumo de carne roja y azúcares (Oddy et al., 2009). Además asocian a los problemas externalizadores, con una dieta de baja calidad (Liu et al., 2004).

En cuanto a investigaciones recientes, con niños desnutridos y su relación con psicopatologías, se encuentra que la desnutrición durante la infancia se asocia a problemas externalizadores en la niñez (Liu et al., 2004).

De nuestro conocimiento, no existen trabajos que hayan realizado una exploración amplia de la salud mental de niños desnutridos. Estos sólo se pueden realizar con instrumentos amplios que midan las principales alteraciones psicopatológicas en los niños. En este sentido, el instrumento más utilizado es el Child Behavior Check List (CBCL 6/18) desarrollada por Thomas M. Achenbach y Craig Edelbrook, que mide de modo fiable los principales síntomas psicopatológicos. No obstante, existen escasos trabajos que hayan utilizado el CBCL/6-18 en niños mexicanos (Albores-Gallo et al., 2007; CEAL-TDAH, 2009; Leiner, Balcazar, Straus, Shirsat y Handal, 2007).

Además, no existe ningún estudio en niños mexicanos que haya utilizado la última versión del CBCL/6-18 que incorpora nuevas medidas psicopatológicas y especialmente, baremos agrupados por culturas para aquellas sociedades en las que no se ha normalizado este instrumento (Achenbach y Rescorla, 2007).

Por ello, el objetivo del presente trabajo ha sido estudiar la presencia de trastornos psicopatológicos asociados a la desnutrición en niños. Hipotetizamos que los niños desnutridos presentarán problemas psicopatológicos comparados con niños de su misma edad y su mismo entorno sociocultural. Además, como objetivo secundario, se estudiará cual es el grupo normativo de referencia multicultural del CBCL/6-18 para los niños mexicanos.

6.2 Material y método

6.2.1 Participantes

Este estudio fue realizado en dos escuelas de Ciudad Juárez, México, se reclutaron 85 niños (39 niños y 46 niñas), de entre 8 y 12 años de edad, que cursaban de tercero a sexto de educación primaria. De la muestra de estudio, 44 niños presentaron desnutrición leve a moderada, y 41 peso normal. Todos los sujetos provenían de status socioeconómico bajo, de entornos urbanos. Como criterios de exclusión se tomaron la presencia de enfermedades neurológicas (parálisis cerebral, epilepsia, lesiones cerebrales, síndromes neurológicos detectados) y enfermedades hormonales (diabetes o enfermedades relacionadas con la tiroides). Previamente se les pidió por escrito a los padres de los niños que firmaran un consentimiento informado. Cabe mencionar que este proyecto, incluyendo el consentimiento informado, fue autorizado por el comité de bioética de la Universidad Autónoma de Ciudad Juárez. Las características demográficas y clínicas de la muestra se pueden ver en la Tabla 1.

Tabla 1. Características socio-demográficas de los niños

Variables	GNP	GD
Sexo de los niños (%)		
Niñas	51.22	56.8
Niños	48.78	43.2
Total	48.2	51.8
Edad de los niños (media y DE)	8. 65 (0.85)	9.09 (1.23)
Estatus socioeconómico		
Bajo (%)	100	100
Ejercicio físico (al menos 1 hora por semana) (%)	100	100

Nota: DE= Desviación Estándar

6.2.2 Medidas Antropométricas

Para la evaluación antropométrica se determinaron medidas básicas (peso y talla) e índices antropométricos (Índice de McLaren, Porcentajes del peso/edad, talla/edad y peso/talla). Las mediciones antropométricas se realizaron según las especificaciones del manual de antropometría del Consejo Nacional de Ciencia y Tecnología (CONACYT) en el 2004. El peso se determinó mediante báscula electrónica marca Seca. La talla se midió en posición de pie, con la cabeza colocada de tal forma que el plano de Frankfurt se situaba en posición horizontal, se utilizó estadímetro marca Harpenden. Los estándares de referencia para peso y talla fueron las curvas y tablas de crecimiento de los Centros para el control y prevención de enfermedades (CDC) del 2000. Para el diagnóstico del estado nutricio se utilizaron las clasificaciones de McLaren y Read (1975) y Waterlow (1972). Considerando como desnutridos a los participantes que presentaron menos del 90% del peso esperado para la edad y la talla.

6.2.3 Medidas Psicopatológicas.

Se utilizó la traducción y adaptación mexicana (Albores-Gallo et al., 2007) de la versión más reciente del CBCL/6-18 (Achenbach y Rescorla, 2007), la cual mide psicopatologías en niños y adolescentes y consta de 113 reactivos, divididos en 8 factores o escalas sindrómicas empíricas, las cuales son: depresión-ansiedad, aislamiento, quejas somáticas, problemas sociales, problemas de pensamientos, problemas de atención, quebrante de normas y conducta agresiva. Las puntuaciones de estos factores se agrupan en dos escalas: problemas internalizadores y problemas externalizadores y estas a su vez en una escala llamada total de problemas. Actualmente cuenta con seis subescalas orientadas al DSM (trastornos afectivos, quejas somáticas, déficit de atención/hiperactividad, trastorno oposicionista y trastorno de conducta). Con la versión de 2007, se añadieron el trastorno obsesivo compulsivo y el trastorno por estrés post-traumático. Para el sistema de corrección se utilizó el sistema informatizado ADM desarrollado por Achenbach (2007).

6.2.4 Procedimiento

Se les pidió a dos escuelas de una zona socioeconómica baja la participación en el proyecto. Se realizó una reunión y se solicitó a los padres el consentimiento informado, mediante un documento en dónde se explicaba el procedimiento que se llevaría a cabo. En los días posteriores se tomaron medidas antropométricas para clasificarlos por estado nutricio. Una vez obtenida la clasificación de la muestra, se les aplicó el CBCL/8-16 a las madres o a los tutores de los niños.

6.2.5 Variables y análisis estadísticos

La variable de agrupación o independiente fue el estado nutricio dividido en dos grupos: normopeso (GNP) y desnutridos (GD).

Como variables dependientes se utilizaron cada uno de los ocho factores y de las dos escalas del CBCL/ 6-18 proporcionadas por el sistema de corrección ADM y el total de problemas. Además de cada una de las escalas orientadas al DSM:

Ansiedad/Depresión (Ans/Dep).

Aislamiento (Ais).

Queja Somática (QS).

Problemas Sociales (PS).

Problemas Pensamiento (PP).

Total de Problemas (Tot P).

Trastorno de Ansiedad (T Ans).

Problemas Somáticos (P Som).

Problemas de Atención (PA).

Quebranto de normas (QN).

Agresividad (Agr).

Internalizadores (Int).

Externalizadores (Ext).

Trastorno afectivo (T Afe).

Trastorno por Déficit de Atención con Hiperactividad (TDAH).

Trastorno Oposicionista (T Opo). Trastorno Obsesivo compulsivo (TOC).

Trastorno de Conducta (P Cond). Trastorno por estrés postraumático (TEPT).

Para los análisis estadísticos, en primer lugar se obtuvieron las puntuaciones T de nuestra muestra aplicando los baremos del Grupo 1, 2 o 3 del software ADM (Achenbach, 2007). Se seleccionó como grupo de referencia normativa aquel que proporcionara puntuaciones T más próximas a 50 en la mayoría de los factores y las escalas.

Posteriormente, se procedió a estudiar las posibles diferencias entre los grupos en las puntuaciones T de los factores y escalas del CBCL incluyendo las escalas DSM. Para esto, se realizó un análisis *t* utilizando la variable grupo diagnóstico como factor (GD vs. GNP), las puntuaciones en los factores, las escalas y la puntuación total de problemas y las escalas orientadas al DSM, como variables dependientes.

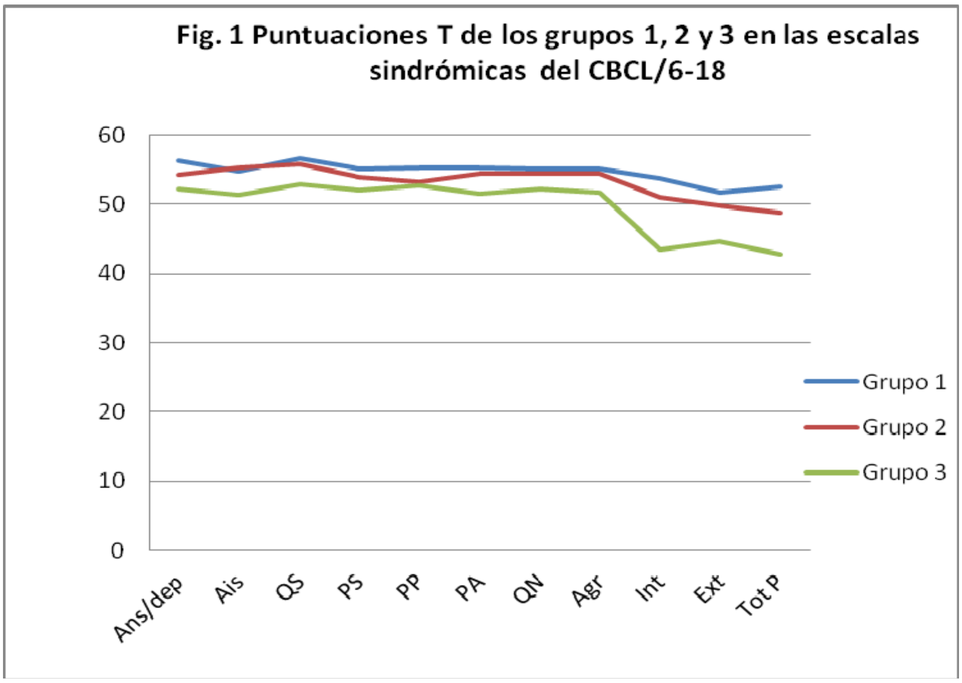
Debido al número de análisis realizados y al carácter exploratorio de esta investigación el nivel de esta significación estadística se fijó al 0.01.

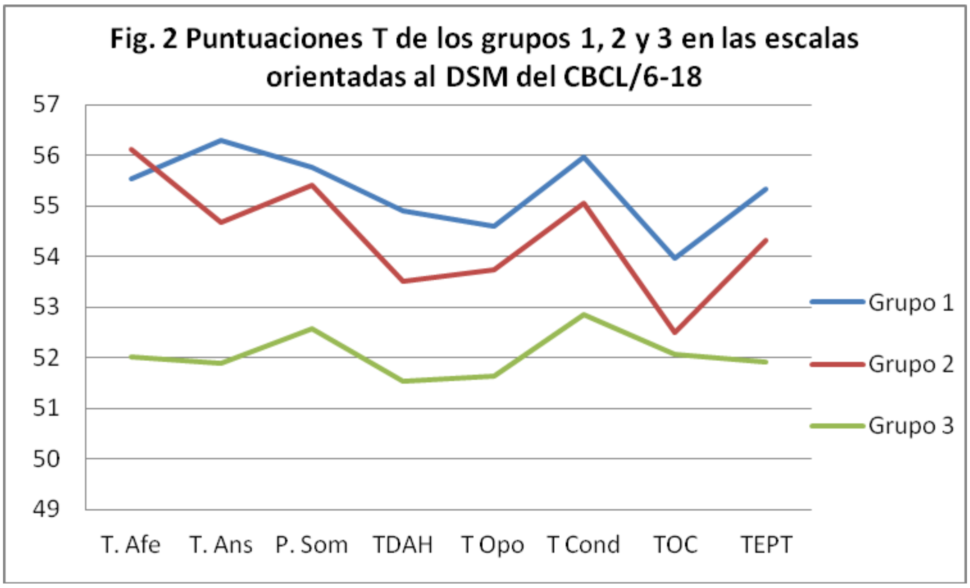
Por último, aplicando los puntos de corte establecidos por Achenbach y Rescorla (2007), se obtuvo el porcentaje de niños que estaban en el límite o dentro del rango de deterioro clínico.

6.3 Resultados

1. *Buscar el grupo de referencia normativo de los baremos multiculturales de Achenbach y Rescorla.*

Se procedió a determinar cual grupo de referencia normativo de estudios internacionales del CBCL (Grupo 1 vs. Grupo 2 vs. Grupo 3) se ajustaba mejor a los niños mexicanos. Como se puede ver en las figuras 1 y 2, el grupo de referencia 3 fue en donde la muestra de niños mexicanos se acercaba más a la medida de 50 en puntuaciones T, en la mayoría de los factores y escalas.





Una vez establecido el grupo de referencia, se obtuvieron las puntuaciones T tanto para el grupo de niños obesos y desnutridos utilizando el grupo de referencia normativo 3 (GN3) y con estas puntuaciones se hizo el resto de comparaciones.

2. *Diferencias entre los niños obesos, desnutridos y normopeso en las escalas de síndromes empíricos y las orientadas al DSM*

Los resultados mostraron que existían diferencias estadísticamente significativas (*p* ajustada a 0.01) para las escalas sindrómicas de problemas sociales, quebranto de normas, trastorno internalizantes, trastornos externalizantes y total de problemas. Muy próximas a la significación se encontraban ansiedad y problemas atencionales (ver Tabla 2).

En el caso de las escalas orientadas al DSM, los resultados mostraron que existían diferencias estadísticamente significativas en entre niños desnutridos y normopeso en la escala de trastorno oposicionista y próximas a la significación la escala de trastorno de ansiedad, TDHA y estrés post-traumático (ver Tabla 2).

Tabla 2. ANOVAs de las escalas del CBCL/6-18

CBCL/6-18	GNP (M y DE)	GD (M y DE)	*t*	*p*
Ansiedad/Depresión	52.20 (5.269)	55.25 (6.172)	2.459	0.016
Aislamiento	51.39 (3.016)	53.48 (5.845)	2.089	0.041
Qujas somáticas	52.83 (4.511)	54.86 (7.312)	1.555	0.124
P. Sociales	51.98 (4.016)	55.18 (6.139)	2.868	0.005
P. De Pensamiento	52.71 (4.020)	54.32 (6.437)	1.394	0.168
P. de atención	51.49 (3.287)	53.86 (5.360)	2.482	0.015
Quebranto de normas	52.29 (4.355)	53.64 (4.473)	1.402	0.165
Conductas agresivas	51.63 (3.246)	54.64 (6.085)	2.864	0.006
Internalizadores	43.56 (10.373)	51.09 (10.909)	3.256	0.002
Externalizadores	44.66 (9.137)	51.18 (9.209)	3.276	0.002
Total de Problemas	42.80 (10.130)	50.82 (10.566)	3.564	0.001
Trastornos afectivos	52.02 (3.991)	54.70 (7.027)	2.181	0.033
Trastorno de Ansiedad	51.90 (3.993)	54.70 (6.447)	2.427	0.018
Problemas somáticos	52.59 (4.318)	55.18 (6.996)	2.074	0.042
TDAH	51.54 (3.613)	53.68 (4.992)	2.281	0.025
Trastono oposicionista	51.63 (2.736)	55.18 (6.510)	3.314	0.002
Conductas	52.85 (5.028)	54.30 (4.517)	1.393	0.167
TOC	52.07 (4.687)	54.39 (5.747)	2.025	0.046
TEPT	51.93 (4.931)	54.95 (6.823)	2.356	0.021

Nota: M= Media, DE= Desviación Estándar

3. Prevalencia de los trastornos sindrómicos y del DSM en niños obesos y desnutridos.

Aplicando los puntos de corte clínicos propuestos por Achenbach y Rescorla (2007), se obtuvo el porcentaje de niños desnutridos que puntuaban en el límite o en el rango clínico en los factores (T => 65), escalas Int, Ext y Tot P (T => 60). Los resultados mostraron que los mayores porcentajes de niños afectados se encontraban en las escalas de ansiedad, quejas somáticas, problemas de pensamiento, internalizantes y externalizantes para las escalas sindrómicas. Para las escalas orientadas al DSM, los mayores porcentajes se encontraban en las escalas de ansiedad, problemas somáticos, trastorno oposicionista y trastorno por estrés post-traumático (ver Tabla 3).

Tabla 3. Porcentaje de niños que se encuentran en el límite o en rango clínico en el CBCL 6/18

CBCL/6-18	Normopeso % (n)	Desnutridos % (n)
Ans/Dep	7.31 (3)	13.63 (6)
Aislamiento	0 (0)	9.09 (4)
Qujas somáticas	0 (0)	13.63 (6)
P. Sociales	2.43 (1)	4.54 (2)
P. De Pensamiento	0 (0)	11.36 (5)
P. de atención	0 (0)	6.81 (3)
Quebranto de normas	7.31 (3)	4.54 (2)
Conductas agresivas	0 (0)	9.09 (4)
Internalizadores	9.75. (4)	18.1 (8)
Externalizadores	4.87 (2)	13.63 (6)
Total de Problemas	2.43 (1)	15.9 (7)
Escalas orientadas al DSM:		
Trastornos afectivos	2.43 (1)	9.09 (4)
Trastorno de Ansiedad	2.43 (1)	13.63 (6)
Problemas somáticos	2.43 (1)	11.36 (5)
TDAH	2.43 (1)	4.54 (2)
Trastono oposicionista	0 (0)	11.36 (5)
Conductas	7.31 (3)	2.27 (1)
TOC	4.87 (2)	9.09 (4)
TEPT	2.43 (1)	13.63 (6)

Nota: n=número de sujetos

6.4 Discusión

El objetivo principal de nuestro trabajo fue estudiar la relación de tres estados nutricios (desnutrición y normopeso) con la salud mental, utilizando el CBCL/ 6-18, escala que hace una exploración amplia de las principales psicopatologías. Para ello, primero determinamos que el grupo multicultural de referencia normativo 3, es el que se ajusta mejor a los niños mexicanos. Usando el grupo normativo 3 como grupo de referencia, encontramos que tanto los niños desnutridos como los obesos presentan alteraciones psicopatológicas.

Considerando las escalas sindrómicas, encontramos que los niños desnutridos padecían tanto trastornos internalizantes como externalizantes comparados con los niños normopeso y considerando las escalas orientadas al DSM, el trastorno oposicionista es el que diferenciaba a los grupos, seguido por trastornos de ansiedad, TDHA y estrés post-traumático.

Existen escasos trabajos que hayan estudiado la psicopatología de los niños desnutridos a pesar de las conocidas conexiones que existen entre los estados nutricionales y la psicopatología (Liu, Raine, Venable, Dalis y Mednick, 2003; Lozoff et al., 2000). De nuestro conocimiento, tan sólo Liu, et al. (2004) investigó el estado psicopatológico de los niños desnutridos encontrando mayor prevalencia de alteraciones externalizadoras. Nuestros datos también han encontrado problemas externalizantes como problemas sociales y quebranto de normas pero, además, ha encontrado una alta frecuencia de problemas internalizantes como problemas de pensamiento o de ansiedad. Probablemente, nuestros resultados están siendo influenciados por la situación de violencia en la que se encuentra Ciudad Juarez en el momento de la evaluación que puede estar más relacionada con el alto porcentaje de problemas internalizantes que hemos encontrado. Si observamos la frecuencia de los problemas en las escalas orientadas al DSM, se puede comprobar que los trastornos de ansiedad y estrés post-traumático son más prevalentes que los problemas de conducta. Sin embargo, esos datos no se han encontrado en los niños normopeso que se encuentran expuestos al mismo contexto y, por tanto, queda por investigar la posible interacción entre el estado nutricional y la vulnerabilidad al desarrollo de problemas psicopatológicos.

Por otro lado, nuestro trabajo ha proporcionado cifras de comparación internacionales para ubicar a los niños mexicanos en los grupos de referencia multicultural de la nueva versión del CBCL. Esto permitirá utilizar esta versión para futuras investigaciones que se desarrollen con niños mexicanos. Además, como la nueva versión incorpora nuevas escalas clínicas como el trastorno obsesivo-compulsivo y el estrés post-traumático, permitirá hacer estudios sobre estos trastornos en futuras investigaciones.

Estos resultados podrían estar limitados por el hecho de que todos los niños pertenecían a un estatus socioeconómico bajo y, por tanto, las prevalencias encontradas estén condicionadas por este factor (a pesar de que el grupo control era del mismo estatus). Otro factor es que el grupo de niños desnutridos presentaba desnutrición leve a moderada. Sin embargo, los resultados obtenidos incluso en estadios leves indicarían la posibilidad de mayores prevalencias en estadios más grave. Futuros estudios deberían comprobar esta hipótesis.

En resumen, los resultados de nuestro estudio indican que los niños desnutridos de Ciudad Juárez presentan alteraciones psicopatológicas tanto internalizantes como externalizantes.

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Capítulo 7. Significant neuropsychological improvement after supplementation with omega-3 in 8 -12 year Mexican malnourished children: A randomized, double blind, placebo and case control clinical trial.

Portillo-Reyes, V., Pérez-García, M., Loya-Méndez, Y., Puente, E. A. *The American Journal of Nutrition*, under review.

7.1 Introduction

Malnutrition is one of the most important nutritional issues during childhood because is in the first years of life when growth is intensive and there still is ripeness of diverse organs. Therefore, consequences will be more serious as younger is the child and more time the malnutrition last (Pollitt, 2000).

Children malnutrition is the result of poor diet, which is related to several biological, socioeconomic and cultural factors (Zlotkin, 2006; Rivera y Sepúlveda, 2003; Watchs, 2000). In the long term, malnutrition can result of damage at cognitive functions and academic performance (Grantham-McGregor et al., 2007). In addition, in the socio-economical terms, the poor countries are the most affected by the ravages of malnutrition and this hampers their development (Branca, 2006).

The main nutritional deficiencies studied in children lie in the lack of protein-energy, iron and essential fatty acids deficiency (Tofail et al, 2008; Walker et al., 2005; Yehuda, Rabinovitz y Mostofky, 2006); and many of these researches tend to focus in the first two years of life, since it is -believed that brain develops intensively during those years (Benton, 2008). Nevertheless, researchers have recently concluded that brain maturation has not been completed in this stage and, in addition it is not uniform (Yeduha, Rabinovitz y Mostofsk, 2006); on the other side, the brain development continues along the infancy, during childhood and up to the adolescence (Ito, 2004; Romine y Reynolds, 2004). Therefore, cognitive and academic deficits in malnourished children during early childhood continue in late adolescence (Walker et al., 2005), because of that, it is necessary to do researches about nutrition in posterior age since it is so that has been explored (Benton, 2008).

Particularly, essential fatty acids (EFA) play an important role in learning faculties and behavior (Johnson et al., 2009; Yehuda, Rabionovitz and Mostofsky, 2005). Deficiency of EFA significantly reduces the size of neurons in the hippocampus, hypothalamus and cerebral cortex (Yehuda, Rabinovitz and Mostofsk, 2006), and leads to a reduction of dopamine in the cortex area (Yehuda and Mostofsky Rabionovitz, 2005). Also ω-3 deficiencies cause a significant reduction of catecholamine, which affect the transport of glucose and its use by the brain. Specifically, DHA is particularly concentrated in synaptic nerve cells where it seems to be involved in signaling processes between neuronal cells

(Youdim, Martín and Joseph, 2000), it controls the activity of neurotransmitters and the neuronal growth factors (Yehuda et al., 2002), it also is a component of cerebral gray matter (Innis, 2008). Although the results are controversial (Hirayama, Hamazaki and Terasawa, 2004; Puri, 2002;), it seems that DHA is crucial for normal cognitive functions (Sinn and Bryan, 2007). Any deviation at physiological levels is associated with cognitive impairment (Yehuda, Rabionovitz and Mostofsky, 1999) and with some developmental disorders such as attention deficit disorder, autism or motor problems (Johnson et al., 2010; Raz and Gabis, 2009; Richardson and Ross, 2000). Overall, these variables could impact on learning performance (Yeduha, Rabinovitz and Mostofsk, 2006).

Summarizing, most studies are characterized by: 1) making the intervention in children under three years and 2) do not make a detailed assessment of neuropsychological functions continue to develop at later ages (Benton, 2008; Walker et al., 2005). Therefore, the objective of this paper is to investigate the ω -3 supplementation effects, in 8 to 12 years children and to know which neuropsychological functions improve after three months of the intervention in a sample of Mexican children with mild to moderate malnutrition. Hypothesize that the intervention group will get clinically relevant improvements in the functions related to memory and executive function as these features are mainly related to the hippocampus and the frontal lobes.

7.2 Method

7.2.1. Recruitment

Participants were drawn from two schools of low socioeconomic status in Ciudad Juarez, Mexico that were willing to assist with the study. The parents of children between 8 to 12 years, were invited to attended a meeting at which the study procedures were explained, written informed consent form the tutors and verbal assent form their children were obtained. In the days following, anthropometric measurements were taken to establish their nutritional status.

7.2.2. Participants

Yield was selected 85 children between 8 to 12 aged. These children were attending 3th to 4th of elementary school. In total, four were not eligible because they did not fulfill or because refused to participate, the inclusion criteria and the remaining 55 of malnourished children were randomly assigned into the study intervention groups and 26 were assigned into the control group (normal nutrition states). See the the flow chart in Figure 1.

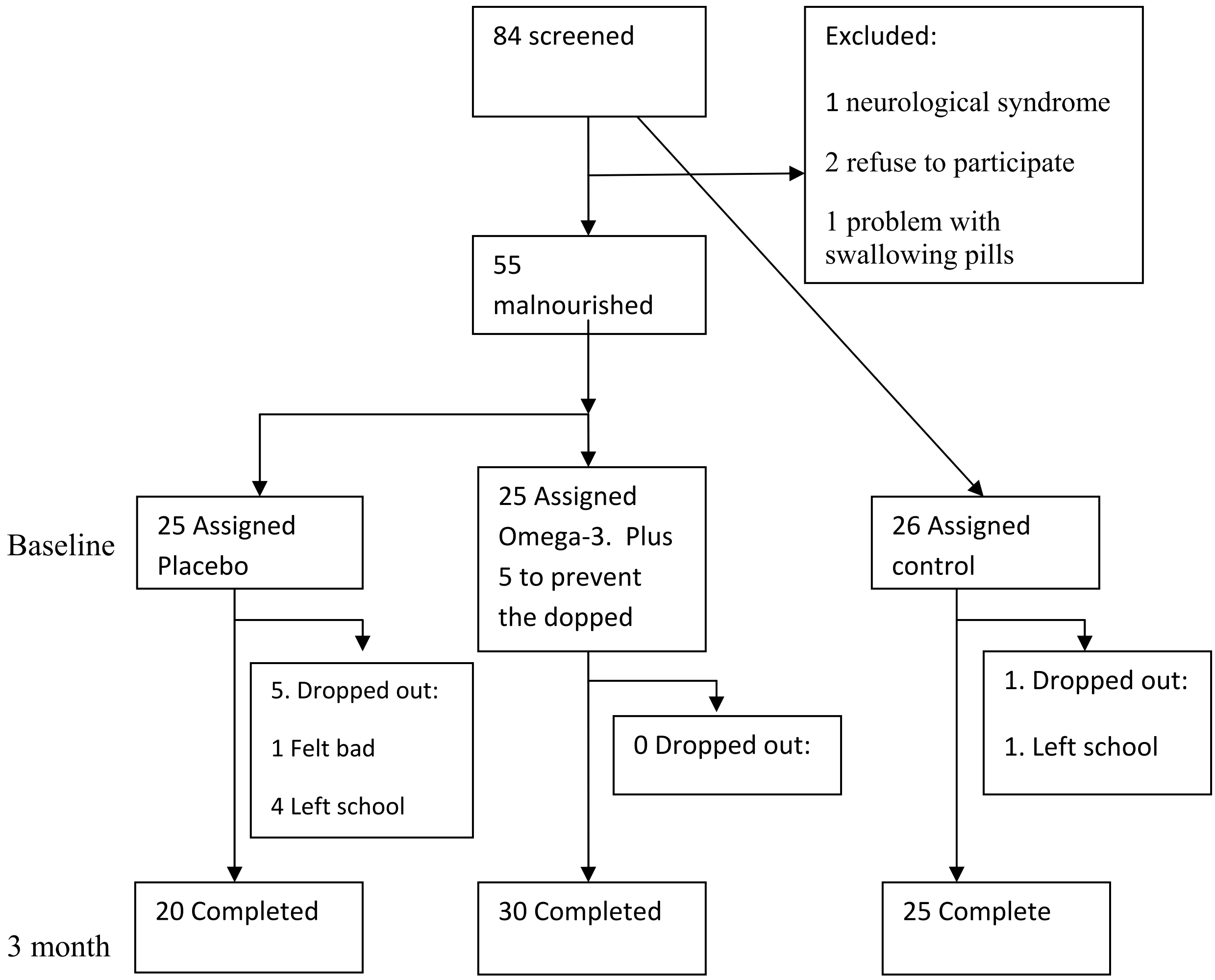

Figure 1. Flow chart of the participants

Inclusion and exclusion criteria

An inclusion criterion was the permission through informed consent from the primary caregiver. Like exclusion criteria were taken the presence of neurological disease (epilepsy, brain injuries, neurological syndromes detected) and hormonal diseases (diabetes or thyroid-related diseases). And were also excluded subjects who had problems swallowing pills or who have ingested the omega-3 supplement or any vitamin supplement in the last six months.

7.3 Study Design

This was a randomized, double blind, placebo-controlled and case control study. The duration of the intervention was three months, because it is the minimum time necessary to have effects on behavior and learning (Kakiraluloma et al., 2008; Richardson and Motgomery, 2005; Richardszon and Puri, 2002), and also is the duration that conforms to standards of other studies that had supplemented with fatty acids. However, it is worth mentioning that at present there is no global consensus on the proper dosage and combination of fatty acids (Richardson y Montgomery, 2005: Castro-González et al., 2004). Then, the primary focus of the study was comparing the effects of parallel treatments for three months. The study was approved by the bioethics committee of the University Autonomous of Ciudad Juarez (UACJ). This trial was registered at clinicaltrials.gov as NCT01199120.

7.4. Intervention

The active treatment was a supplement containing omega-3 fish in gelatin capsules. The daily dose consist of three capsules provided ω-3 fatty acids (60 mg of DHA and 90 mg of EPA each capsule). Placebo treatment consist of soya oil capsules, were similar than the active treatment.

Treatment was administered by teachers twice daily, (one early in the morning and other at lunchtime). The afternoon capsule and the doses of weekends and holidays were administrated by the parents. Both, parents and teachers were given a calendar marked intake where they supplemented each time the child, this calendar will be delivered every two weeks. This information was completed with unused capsule counts. Baseline measures were completed and repeated at 3 months.

7.5 Measures

Anthropometric measures

Anthropometrics measurements were identified as core measures (weight and height) and anthropometric index (McLaren index, percentages of weight/age height/age and weight/height). The anthropometric measurements were performed according to specifications of the anthropometry manual from National Council for Science and Technology (CONACYT) (Aparicio, et al, 2004). The weight was determined by a Seca ® electronic scale. The size was measured in a standing position, with the head placed so that the plane of Frankfurt was in horizontal position, a Harpenden stadimeter was used to get these measurements. All subjects were wearing light clothes and no shoes during the anthropometric data collection phase. The reference standards for weight and height were the curves and growth tables taken from the Center for Diseases Control (CDC) in 2000.The cutoff points to MG was 85-95% in height/age and 70-90% in weight/height, for the NNG was 95-105 and 90-110% respectively (Waterlow, 1972).

Omega-3 Consumption

The children's parents were asked to answer a questionnaire about the consumption frequency of food with high content of omega 3, including most consumed products offered at the local markets. The consumption was registered by rations, using the Mexican equivalents system. The content has been quantified in gr of omega 3 per each 100 gr of the aliment, in the case of fish, using the USDA lists as source of information. For high concentration of omega 3 aliments frequently used, it has been quantified according to the reported products' nutrimental labels. It has also been considered the omega 3 supplementation.

Neuropsychological measures.

The neuropsychological test battery was selected for measure the following neuropsychological domains:

- Processing Speed:

- Symbol Search (SS). Subtest of Wechsler Intelligence Scales for Children (WISC-IV) (Wechsler, 2007). Requires examines match symbols appearing in different groups.

- Viso-perceptive integration:

  - Embedded Figures Test (EFT). This is a subtest of the Evaluación Neuropsicológica Infantil (ENI) (Matute, Rosselli, Ardila y Ostrosky-Solís, 2007). The child is asked to find a figure as quickly and accurately as possible in a larger complex design in which it is embedded.

  - Visual Closure (VC).This is a subtest of the ENI (Matute et al., 2007), and consists in complete visual patterns when only one or more parts of the object are presented.

- Visomotor Coordination

  - TMT A (Reitan, 1958). The subject in Part A, must join with lines the numbered circles in consecutive form.

  - Block Design (BD) (Wechsler, 2007). This test requires taking blocks that have all white sides, all red sides, and red and white sides and arranging them according to a design.

- Attention:

  - Letter Cancellation (LC) (Matute et al., 2007). The task consists to mark the letters "X" only when, it is preceded by the letter A in a segment with different distracter letters as fast as possible.

- Memory:

  - Rey Complex Figure (REY) (Rey, 1987). In which examinees are asked to reproduce a figure, first by copying and three minutes after from memory.

  - Word List (WL). Participants memorize a list of 12 words. The list was presented four times and participants were required to recall as many words as possible after each presentation. After half an hour, they were asked to recall the 12 original target words. Participants were then with a list of distracter words and asked to recall those. Following a filled delay, participants were again asked to recall by categories the original 12 target words (Matute et al., 2007).

- Language
    - Comprehension instruction (Com Inst). Measure the ability to comprehend the reading, through a series of instructions (Matute et al., 2007).
    - Semantic fluency (animals). This task consists in saying all the names of animals –reminded by the subject in a minute period. The task excluded, repeated words, or referrals as “pollo” “pollito” (Matute et al., 2007).
- Executive Function:
    - Letter-Number Sequencing (L&N): This subtest of the WISC-IV consists in giving the subject a mixed set of numbers and letters orally and the subject has to complete two tasks. First, the subject has to arrange the numbers in ascending order orally and then arrange the letters in alpha order orally from the previously given set (Wechsler, 2007).
    - Matrix Reasoning (MR). The purpose is to complete the picture matrix with any of the given solutions (Wechsler, 2007).
    - Stroop color and word test (Golden, 2005): The test contains three lists. Children have to read words in the first list, say the name of colors in the second list, and say the name and color of the printed words as quickly and as accurately as possible in 45 seconds per task in third list.
    - TMT-B: Shifting. In part B, Children must join circles with numbers and letters in alternative form (Reitan, 1958).
- Absenteeism. Was estimated by the number of times a student not attended class in the bimester beforeanterior and afterposterior the supplementation.

- Academic performance (Acad Perf). Academic performance was the average of the ratings that the children had in the subjects of Spanish, Mathematics, History and, Geography, Science and Civic education.

7.6 Statistical Analyses.

All data were analyzed by the authors using the Statistical Package for Social Sciences (SPSS) version 15.

First, it was ensured that the groups were equally distributed among the demographic variables of the children and their mothers by chi-square test.

Then, a mixed ANOVA (3x2) was conducted with the variable “group” (intervention vs placebo vs control group) and “moment” (pre-intervention vs post-intervention group) as factors. If statistical signification was reached for main effects or interactions, Sheffe post hoc comparisons were conducted to analyze between group differences. Neuropsychological variables were the dependent variables.

Cohen’s Delta was obtained for all the comparisons. After that, in order to know the amount of children which reached a large improvement according to Cohen’s criteria, each children was classified in three groups: 1) no improvement: if delta was between 0 and 0.5; 2) medium size improvement: if delta was between 0.51 and 0.8; and 3) large size improvement: if delta was bigger than 0.8. Chi-square analyses were conducted to know the statistical significance of the improvement frequency in each group. Statistical significance was established at 0.002 after Bonferroni adjustment.

7.7. Results

First, it was ensured that the groups were equally distributed in the demographic variables of the children and their mothers. Results showed that there were no statistically significative differences in the age IQ, absenteeism or academic performance of children. Neither were statistically significative differences in age, IQ, academic level or economical status of their mothers (see Table 1).

Table 1. Sociodemographics Characteristic

	TXG	Placebo	NNG
Age of Mother (Mean / SD)	32.16 (4.37)	32.47 (5.00)	34.24 (5.72)
Mother's Education (%)			
Elementary school	13.3	5	4
Elementary school not completed	0	0	4
Secondary	30	30	24
Secondary not completed	3.3	5	12
High School	30	45	20
High School not completed	3.3	5	4
Technical degree	16.7	5	20
Bachelors degree	3.3	5	12
Mother's IQ (Mean/SD)	84.03 (9.70)	84.42 (10.50)	84.68 (7.66)
Child IQ (Mean/SD)	87.00 (12.30)	94.25 (19.51)	90.22 (23.68)
Child Gender (%)			
Female	23.07	17.94	17.94
Male	15.38	11.53	14.1
Total	38.45	29.47	32.04
Child age (Mean/SD)	9.37 (1.173)	9.08 (.985)	9.06 (.944)
Social-economic status (%)			
Medium - Low	100	100	100
Academic performance	7.328 (1.08)	7.496 (1.08)	7.992 (1.025)
Scholar absenteism	2.00 (2.259)	2.476 (3.641)	.708 (.999)
Physical activity performed (at least one hour per week) (%)	100	100	100
Height	1.28 (0.07)	1.27 (0.06)	1.31 (0.07)
Weight	23.63(5.61)	23.56 (2.88)	28.26 (3.90)
BMI	18.85 (2.10)	18.46 (1.41)	21.44 (2.07)

Note: SD= Standar Desviation ; BMI = Body mass index

Neuropsychological differences between groups, before and after the intervention.

Secondly, we studied if there were differences among the three groups before and after the intervention.The results show that only the TXG improved in SS [*F*= 6.21; p<0.003], BD [*F*= 10.67; p<0.000], L&N [*F*= 3.73; p<0.029], MR [*F*= 5.27; p<0.007], LC [*F*= 3.69; p<0.030], EFT [*F*= 7.28; p<0.001],VC [*F*= 4.79; p<0.001], Stroop-color [*F*= 4.25; p<0.018], Acad Perf [F= 3.69; p<0.030] (see Table 2).

Effect size and percentages of improvements by group

Then we proceeded to study the size of the differences. The results showed that there were differences in Cohen's delta between the three groups of SS, EEF, VC,BD, LC and MR.

Finally, in 11 of the 18 neuropsychological variables studied, more than 50% of children in the treatment group had greater improvement according to the criteria of Cohen´s (delta> 0.8). Is worth mention that in processing speed (SS), coordination visomotor (BD), perceptual integration (EFT), attention (CL) and executive funtion (L&N and MR), that improved was present in more than 70% of supplemented children (see Table 3).

Tabla 2. Differences in pre-post neuropsychological variables in treatment, placebo and control groups.

Dominie	Variable	TxG(meand and SD) Pre	TxG(meand and SD) Pos	PlG (meand and SD) Pre	PlG (meand and SD) Pos	CG (meand and SD) Pre	CG (meand and SD) Pos	Efecto	*F*	*p*	Post Hoc	
Processing Speed	Symbol Search	16.065 (4.135)	19.933 (4.456)	18.809 (6.104)	20.047 (5.267)	18.208 (4.393)	19.291 (4.227)	Pre Pos	29.23	0.000	Placebo	0.021
								PP* Dx	6.21	0.003	Tx	0.000
											Control	0.000
Vispoerceptual integration	Embedded Figures	10.800 (1.936)	12.300 (1.822)	10.666 (2.456)	11.000 (2.569)	11.208 (1.718)	11.083 (1.501)	Pre Pos	9.077	0.004	Placebo	0.391
								PP* Dx	7.28	0.001	Tx	0.000
											Control	0.671
	Visual Closure	4.233 (1.250)	5.200 (1.270)	3.809 (1.661)	4.1422 (1.621)	4.166 (0.761)	4.333 (0.963)	Pre Pos	17.311	0.000	Placebo	0.090
								PP* Dx	4.79	0.001	Tx	0.000
											Control	0.405
Visoconstructive integration	Block Design	21.500 (8.240)	28.333 (8.138)	22.428 (10.254)	22.571 (9.303)	20.041 (8.121)	21.500 (7.575)	Pre Pos	18.626	0.000	Placebo	0.876
								PP* Dx	10.674	0.000	Tx	0.000
											Control	0.252
	TMT-A	93.766 (47.342)	76.433 (44.961)	84.684 (26.119)	75.842 (33.992)	86.041 (30.240)	66.58 (22.936)	Pre Pos	14.034	0.000		
								PP* Dx	0.564	0.571		
Attention	Letter Cancellation	20.333 (7.702)	23.733 (6.329)	20.095 (8.383)	21.857 (7.882)	20.666 (6.571)	12.875 (6.641)	Pre Pos	12.704	0.001	Placebo	0.004
								PP* Dx	3.69	0.030	Tx	0.002
											Control	0.805
ENI: Verbal Memory	Verbal inmediatly recall	22.166 (8.530)	27.700 (5.627)	21.381 (5.142)	25.285 (5.857)	21.916 (6.013)	24.166 (4.400)	Pre Pos	20.772	0.000		
								PP* Dx	1.344	0.267		
	Verbal free recall	6.700 (2.561)	8.166 (1.743)	7.000 (2.509)	7.619 (1.774)	6.833 (1.711)	7.125 (1.776)	Pre Pos	8.028	0.006		
								PP* Dx	1.743	0.182		
	Verbal cue recall	6.833 (2.422)	8.533 (1.851)	6.904 (2.071)	8.142 (1.681)	7.250 (1.799)	7.583 (1.501)	Pre Pos	17.983	0.000		
								PP* Dx	2.599	0.081		
	Verbal recognition	20.733 (3.268)	22.066 (1.460)	21.666 (1.425)	21.714 (2.028)	20.916 (3.161)	21.125 (2.383)	Pre Pos	2.326	0.132		
								PP* Dx	2.980	0.235		
REY: Visual Memory	Visual inmediatly recall	11.433 (6.508)	14.700 (7.355)	11.023 (6.664)	10.809 (5.801)	11.854 (6.509)	10.666 (5.155)	Pre Pos	0.540	0.465		
								PP* Dx	2.842	0.065		
Languaje	Animal	10.233 (5.738)	11.600 (2.931)	9.619 (3.169)	11.000 (3.331)	10.083 (3.361)	10.333 (3.422)	Pre Pos	7.894	0.006		
								PP* Dx	1.11	0.336		
	Comprehension instruction	7.483 (1.600)	8.283 (1.498)	7.857 (1.074)	8.428 (1.154)	7.875 (1.200)	8.125 (1.141)	Pre Pos	17.923	0.000		
								PP* Dx	1.868	0.162		
Executive Function: Reasoning	Matrix Reasoning	11.966 (4.139)	14.033 (3.782)	12.523 (3.515)	13.095 (3.448)	13.833 (4.187)	13.666 (4.400)	Pre Pos	7.467	0.008	Placebo	0.343
								PP* Dx	5.27	0.007	Tx	0.000
											Control	0.761
Executive Function: Working memory	Letter-Number Sequencing	9.633 (5.404)	12.366 (3.498)	9.523 (4.812)	10.809 (4.308)	10.291 (6.701)	9.875 (4.386)	Pre Pos	5.962	0.017	Placebo	0.019
								PP* Dx	3.73	0.029	Tx	0.002
											Control	0.689
Executive Function: Shifting	TMT-B	190.037 (74.369)	171.888 (55.339)	184.294 (85.866)	173.058 (88.387)	202.523 (100.339)	185.666 (80.801)	Pre Pos	1.505	0.224		
								PP* Dx	0.027	0.974		
Executive Function: Inhibition	Stroop Word	60.300 (14.506)	64.733 (13.449)	56.66 (15.589)	59.000 (16.136)	56.041 (16.543)	61.750 (10.147)	Pre Pos	4.949	0.290		
								PP* Dx	0.252	0.778		
	Stroop Color	44.566 (10.624)	48.533 (9.821)	43.523 (9.790)	40.857 (9.079)	42.250 (6.495)	45.333 (7.148)	Pre Pos	2.223	0.140	placebo	0.109
								PP* Dx	4.251	0.018	TX	0.021
											Control	0.092
	Stroop Color-Word	22.566 (5.411)	27.260 (6.979)	23.333 (5.121)	24.381 (4.609)	23.791 (6.560)	24.916 (5.625)	Pre Pos	10.185	0.002		
								PP* Dx	3.049	0.054		
Absenteeism		2.000 (2.259)	1.366 (1.629)	2.476 (3.641)	1.619 (1.283)	.708 (.999)	1.041 (.708)	Pre Pos	13.753	0.057		
								PP* Dx	3.699	0.390		
Academic performance		7.328 (1.087)	7.900 (0.944)	7.496 (1.083)	7.919 (1.163)	7.992 (1.025)	8.054 (1.014)	Pre Pos	18.838	0.000	Placebo	0.011
								PP* Dx	3.699	0.030	Tx	0.000
											Control	0.695

7.8 Discussion

Our study was designed to investigate the cognitive effects of omega-3 supplement in malnourished children. When the frequency questionnaire results were analyzed, they showed a poor consumption of aliments rich in omega 3. The applied tests revealed that only 8% of the children consumed a ration of fish two or more times a week, 39% one ration a week, 19% a ration every two weeks and 34% a ration a month. Of them 55% consumed only canned tuna and 13% sardines in tomato sauce. The most consumed fish were tilapia, trout, hake and salmon. The frequency of aliments enriched in omega 3 was very low, only 10% of the evaluated children revealed consumption about two or more times a week, most of them in milk. These results confirm the necessity of supplement with omega 3 fatty acids.

Our results shows omega-3 supplementation for three months has effects on some neuropsychological variables. The effects do not depend on the degree of maternal education, age or IQ of the mother considered a good predictor of child IQ (Menezes-Filho, Novaes, Moreira, Sarcinelli and Mergler, 2011). It is important to note that our study was controlled by a control group and a placebo group, when most studies do not consider these variables (Kirby, Woodward y Jackson, 2010). We found significant differences between the treatment, placebo and control group before and after the intervention in processing speed (search symbol), visoperceptual integration (superimposed pictures and visual closure),visual coordination (block design) and in the executive function (matrix reasoning and working memory). In some neuropsychological skills, children with placebo have improvements, but not equally to the treatment group; we believe that being actively involved may have caused this effect.

Table 3. Means, standard deviations and % of children by groups with delta > 0.8 in each neuropsychological variables

Dominio	Variable	TxG (Mean and SD)	PIG (Mean and SD)	CG (Mean and SD)	*F*	*p*	Sheffee	% of children with delta > 0.8 TxG %(n)	PIG %(n)	CG %(n)
Processing Speed	Symbol Search	0.900 (0.868)	0.264 (0.482)	0.251 (0.785)	6.576	.002	a	77.27 (17)	9.09 (2)	13.63(3)
Vispoerceptual integration	Embedded Figures	0.834 (0.733)	0.014 (0.424)	0.185 (0.775)	10.768	.000	a	77.27 (17)	4.54 (1)	21.05 (19)
	Visual Closure	0.767 (0.896)	0.203 (0.521)	0.193 (1.117)	3.657	.031	b	38.88 (7)	16.66 (3)	44.44 (8)
Visoconstructive integration	Block Design	0.834 (0.733)	0.014 (0.424)	0.185 (0.775)	10.768	.000	a	77.27 (17)	4.54 (1)	21.05 (19)
	TMT-A	0.375 (.825)	-0.294 (0.832)	-0.731 (1.313)	1.217	.302		20 (1)	40 (2)	40(2)
Attention	Letter Cancellation	0.484 (0.759)	0.216 (0.308)	0.031 (0.618)	3.681	.030	b	77.77 (7)	11.11 (1)	11.11 (1)
ENI: Verbal Memory	Verbal inmediatly recall	0.781 (1.142)	0.710 (1.101)	0.431 (1.402)	.586	.559		45.45 (15)	21.21 (7)	33.33 (11)
	Verbal free recall	0.681 (1.301)	0.289 (0.939)	0.167 (1.225)	1.397	.254		48.27 (14)	24.13 (7)	27.58 (8)
	Verbal clue recall	0.795 (1.134)	0.660 (0.857)	0.202 (1.426)	1.803	.172		53.57 (15)	25 (7)	21.42 (6)
	Verbal recognition	0.564 (1.315)	.027 (0.887)		1.600	.209		55.55 (10)	16.66 (3)	27.78 (5)
REY: Visual Memory	Visual inmediatly recall	0.471 (1.117)	-0.034 (0.969)	-0.203 (1.295)	2.582	.083		50 (8)	25 (4)	16 (4)
Language	Animal	0.315 (0.639)	0.424 (0.839)	0.073 (1.058)	1.036	.360		30 (6)	45 (9)	20.83 (5)
	Comprehension instruction	0.516 (0.686)	0.513 (0.955)	0.195 (0.951)	1.135	.327		33.33 (9)	37.03 (10)	29.62 (8)
Executive Function: Reasoning	Matrix Reasoning	0.521 (0.618)	0.164 (0.773)	-0.038 (0.616)	4.944	.010	b	70 (7)	30 (3)	0 (0)
Executive Function: Working memory	Letter-Number Sequencing	0.614 (1.011)	0.282 (0.505)	-0.075 (0.908)	4.246	.018	b	66.66 (10)	13.33 (2)	20 (3)
Executive Function: Shifting	TMT-B	0.279 (1.250)	-0.129 (1.114)	-0.186 (1.333)	.082	.921		30(3)	30(3)	40 (4)
Executive Function: Inhibition	Stroop Word	0.317 (1.130)	0.147 (0.790)	0.427 (1.404)	.337	.715		52.38 (11)	14.28 (3)	33.33 (7)
	Stroop Color	0.387 (0.873)	-0.282 (0.772)	0.450 (1.259)	3.797	.027	d	42.10 (8)	10.52 (2)	47.37 (9)
	Stroop Color-Word	0.747 (1.100)	0.215 (0.892)	0.187 (1.053)	0.075 (1.324	.085		50 (12)	20.83 (5)	29.17 (7)
Academic performance		0.0751 (0.084)	0.054 (0.089)	0.007 (0.094)				N/A	N/A	N/A

Note: a= TX> (Placebo = control); b= Tx > Control; Placebo = TX y control; c= TX > placebo; control = tx y placebo;d= tx= plcebo= control.

This pattern of results shows a more widespread pattern of adverse effects related to structural (Yehuda et al., 2006) and another pattern of a specific effect of some brain areas. On the first pattern, our results have shown an increase in processing speed of children. This result could be explained by the effects that omega-3 has on the membrane of the neuron, the synapses and myelin (Yehuda et al., 2006). In addition, similar works found the same results with the omega-3 supplementated (Cheatham, Nerhammer, Asserhoj, Michaelsen and Lauritzen, 2011).

On the other hand, we have found benefits associated with different functions in brain areas. First, we found an improvement in visoperceptual tests. This result corroborates several studies that have shown improvement in visual processing areas after supplementation with omega 3 (Kirby et al., 2010), even in new born early months (Birch et al., 2010). However, our results would show that this improvement can be achieved in the age window selected for this study.

We have also found improvements in sustained attention, which is associated especially with the development of ADHD. In fact, previous studies have used the omega-3 supplementation for improving attentional problems of children with ADHD disorder with mixed results (Johnson et al., 2009; Richardson & Puri, 2002). Therefore, our results would support such intervention since, at least in our sample, we found that improvement. These results are also consistent with studies indicating that omega-3 is related to the increased availability of dopamine in the brain cortex (Yehuda et al, 2005).

Likewise we found a significant improvement in the update component of executive function such as abstract reasoning and working memory. These results are consistent with previous studies that have found improvements in these functions after supplementation, even though not at this age. However, we hypothesized that the high numbers of children have improved in the treatment group because the intervention was conducted in this period for this particular function. In addition, the findings on the role of omega 3 on the enhanced availability of neurons in the cortex and their role with the increased availability of dopamine as well, may explain these findings (Yehuda et al., 2005).

Like many authors, we found no differences in any of the memory variables (Muthayya et al., 2009). This could show the specificity of the effects of omega 3 and would suggest not using global measures of cognitive performance. Moreover, this effect is not dependent on improved processing speed since memory tests measure precision not speed. However, these results do not support our initial hypothesis that expected an improvement in memory due to previous findings on the role of omega 3 in the number of neurons in the hippocampus. Although this improvement has occurred in the intervention group also occurred in the other groups showing that memory is more sensitive to external stimulation to the effect of omega 3.

As far as we know, this is the first study of omega-3 supplementation where is considered the magnitude of change for each participant. We found large changes in malnourished children supplemented with omega-3 that were not observed in placebo malnourished children, or control children in the neuropsychological variables. These results show significant increases over 70% of children in the supplemented group and throw light on the clinical significance beyond the statistics relevance. Although no previous studies with only omega-3 supplementation in malnourished children aged 8-12 have been carried out with, a similar study found no significant improvement postoperatively (Muthayya et al., 2009). The difference in design, supplements and neuropsychological tests do not allow comparisons between these two studies.

However, these results may be limited by two factors. First, all children in the sample belonged to the same socioeconomic status and, second, all children were of a mild-moderate malnutrition.

In summary, the results of our study show a specific effect of supplementation with omega 3 in processing speed, visoperceptual capacity, attention and the updating component of executive function.

Capítulo 8. Discusión general, conclusiones y perspectivas futuras.

8.1 Discusión General

El objetivo principal de esta tesis consistió en estudiar el rendimiento neuropsicológico de los niños con desnutrición leve a moderada y, probar el efecto de la suplementación con el ácido graso omega-3 en el rendimiento neuropsicológico. Al revisar los estudios realizados en este tema, nos dimos cuenta que no controlaban, en el mismo estudio, variables como la edad, el nivel educativo y la inteligencia de la madre, tampoco el nivel socioeconómico, dichas variables son importantes porque influyen directamente sobre la inteligencia. También observamos que ninguno media ampliamente las psicopatologías, el rendimiento académico ni tampoco exploraba a profundidad las habilidades neuropsicológicas.

Por lo tanto nuestros estudios los dirigimos a una serie de objetivos que pueden resumirse en (i) Indagar si la desnutrición leve a moderada afectan al CI y al rendimiento académico, (ii) conocer si la desnutrición leve a moderada está asociada a trastornos psicopatológicos, (iii) estudiar si la desnutrición leve a moderada afecta al funcionamiento ejecutivo y, (iv) conocer si la suplementación con el acido omega-3 mejora las funciones neuropsicológicas de los niños con desnutrición leve a moderada.

De modo global, se puede decir que los niños con desnutrición leve a moderada presentan una bajada de CI comparados con los niños normopeso, están afectados tanto por trastornos externalizantes como internalizantes, presentan problemas de función ejecutiva que se relacionan con su rendimiento académico pero que mejoran en velocidad de procesamiento, habilidades visoperceptivas, atención y en el componente de actualización de la función ejecutiva tras la suplementación con omega 3.

Estos hallazgos tienen importantes implicaciones en cuanto a la prevención e intervención. A nivel escolar, es importante considerar que los deterioros neuropsicológicos encontrados como problemas de memoria, función ejecutiva o lenguaje pueden tener influencia en el rendimiento académico de los niños (Kar, Rao y Chandramoulil, 2007; Guxens *et al*. 2009). Aunque no son la única causa de fracaso escolar en niños desnutridos, la relación entra las alteraciones neuropsicológicas y el rendimiento académico en estos grupos debería ser estudiado en el futuro. Además también se debería investigar la utilidad de programas de intervención neuropsicológica sobre estas alteraciones.

También deben ser considerados desde un punto de vista clínico. Las psicopatologías de mayor frecuencia en los niños desnutridos en las escalas síndrómica empíricas son: problemas de ansiedad/depresión, quejas somáticas y trastornos de pensamiento, indicando mayor prevalencia de trastornos internalizadores. Considerando las escalas orientadas al DSM, los trastornos de ansiedad, los somáticos y los oposicionistas son los más frecuentes. Existen escasos trabajos que hayan estudiado la psicopatología de los niños desnutridos. De nuestro conocimiento, tan sólo Liu et al. (2004), investigó esto encontrando mayor prevalencia de alteraciones externalizadoras. Los resultados obtenidos con niños con desnutrición leve apuntarían a mayores prevalencia en estadios más grave. Y nos muestran la evidencia de que los niños con estadios nutricionales alterados presentan sintomatología asociada a patologías.

En general estos resultados son importantes, ya nos muestran la importancia de crear programas nutricionales de prevención y tratamiento efectivos en estas etapas tempranas de la vida, ya que estudios apuntan a que los problemas de alteraciones nutricionales pueden incluso repercutir en la vida adulta (Yehuda, Rabionovitz y Mostofsky, 2006; Walker et al., 2005). Además estos estados nutricios alterados contribuyen a aumentar los costos gubernamentales como la atención de la salud pública y la disminuyen la productividad (McLachlan, 2006); obstaculizando el desarrollo de los países pobres socioeconómicamente hablando (Branca, 2006; Grantham-McGregor et al., 2007).

8.2 Conclusiones

1. El cociente intelectual se encuentra relacionado con el rendimiento académico de los niños desnutridos y obesos.

2. Los niños desnutridos presentan problemas de función ejecutiva que se relacionan con su rendimiento académico.

3. Las alteraciones psicopatológicas más frecuentes en niños desnutridos son los trastornos de conducta, los trastornos de ansiedad y el estrés post-traumático.

4. La suplementación a niños desnutridos con Omega-3 beneficia en habilidades neuropsicológicas como: Velocidad de procesamiento, atención, integración visoperceptual y la función ejecutiva pero no en la memoria ni en el lenguaje.

8.3 Perspectivas futuras

Algunas de las perspectivas futuras derivadas de esta investigación son:

1.- Extender nuestro estudio a niños de diferentes estatus socioeconómico. Para ello sería recomendable tomar la muestra de distintas escuelas, ya sea públicas y/o privadas, según los distintos sectores socioeconómicos, de acuerdo al Plan de Desarrollo Urbano de la ciudad.

2.- Analizar la dieta de los niños y relacionarla con las distintas habilidades neuropsicológicas, ya que ésta pude estar asociados a alteraciones cognitivas.

3.- Estudiar si la dieta de los niños pude estar relaciona y/o depender de la genética.

4.-Determinar si la desnutrición y la obesidad comparten mecanismos de alteración neuropsicológica.

5.- Expandir nuestra investigación a otros estados nutricios como desnutrición grave y sobrepeso. Con la desnutrición grave debido a que suponemos que si encontramos resultados significativos en niños con desnutrición leve, obtendremos resultados más significantes en estadios de desnutrición más severos. Al igual que posiblemente encontremos que los niños con sobrepeso ya tienen marcadores de repercusiones neuropsicológicas.

6.- Hacer un seguimiento de los niños suplementados para ver si las mejoras en el área neuropsicológica se perdieron o persisten. Incluso extender la suplementación a otros estados nutricios como lo es la obesidad y posiblemente a niños sanos (esto debido a la evidencia de carencia de omega-3) y, medir además de las habilidades neuropsicológicas, la sintomatología psicopatológica, para ver si disminuye.

Referencias

Achenbach, T.M. (2007). User guide for Assesment Data Manger (ADM). Burlington, VT. University of Vermont. Research Center for Children, Youth & Families.

Achenbach,T.M. y Rescorla, L.A. (2007). Multicultural guide for the ASEBA School-Age form & profiles. Burlington, Vt. University of Vermont. Research Center for Children, Youth & Families.

Alaimo, K., Olson, C.M. y Frongillo, E.A. (2001). Food insufficiency and American school-aged Children's cognitive, academic, and psychosocial development. *Pediatrics*, *108*, 44-53.

Albores-Gallo, L., Lara-Muñoz, C., Esperón-Vargas, C., Cárdenas, J.A., Pérez, A.M. y Villanueva, G. (2007). Validez y fiabilidad del CBCL/6-18. Incluye las escalas del DSM. *Actas Españolas de Psiquiatría, 35(6),* 393-399.

Amigo H. (2003). Obesidad en el niño en América Latina: situación, criterios de diagnóstico y desafíos. *Cadernos de Saúde Pública,* 19 (Suppl. 1), 163-170.

Aparicio, R.M., Estrada, A.L., Fernández, C., Hernández, R.M., Ruiz, M., Ramos, D., Rosas, M., Valverde, E. & Angeles, E.(2004). *Manual de Antropometría*. 2nd ed. Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, CONACYT: México.

Arija, V., Esparo, G., Fernandez-Ballart, J., Murphy, M.M., Biarnes, E., y Canals, J. (2006).Nutritional status and performance in test of verbal and nonverbal intelligence in 6 year old children. Intelligence, 34, 141–149.

Avila, C.A., Shamanh, T., Chávez, A. y Galindo, G. C. (2003). *Encuesta Urbana de Alimentación y Nutrición en la Zona Metropolitana de la Ciudad de México 2002*. México, D.F.: Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán. Instituto Nacional de Salud Pública.

Azurmendi, A, Braza, F, Sorozabal, A, García, A., Braza, P., Carreras, M.R., Muñoz, J. M., Cardas, J. y Sánchez-Martín, J. R. (2005). Cognitive abilities, androgen levels, and body mass index in 5-year-old children. *Hormones and Behavior, 48,* 187-195.

Bacardí-Gascón, M., Jiménez-Cruz, A., Jones, E. y Guzmán-González, V. (2007). Alta prevalencia de obesidad y obesidad abdominal en niños escolares entre 6 y 12 años de edad. *Boletín Médico del Hospital Infantil de México, 64,* 362-369.

Ballesteros, F., Sejas, M., Herbas, A. y Carpentier, I. (2007). Síndrome metabólico y su relación con ácidos grasos Omega 3. *Revista Boliviana de Química, 24 (1),* 58-63.

Bazar, K.A., Yun, A.J., Lee, P.Y., Daniel, S.M., Doux, J.D. (2005). Obesity and ADHD may represent different manifestations of a common environmental oversampling syndrome: a model for revealing mechanistic overlap among cognitive, metabolic, and inflammatory disorders. *Medical Hypotheses, 66,* 263-269.

Beard, J. (2007). Recent evidence from human and animal studies regarding iron status and infant development. *Journal of Nutrition, 137 (2),* 524-530.

Benton, D. (2008). The influence of children´s diet on their cognition and behavior. *European Journal of Nutrition, 47 (3),* 25-37.

Benton, D., Ruffin, H. P., Lassel, T., Nabb, S., Messaoudi, M., Vinoy, S, Desor, D. y Lang, V. (2003). The delivery rate of dietary carbohydrates affects cognitive performance in both rats and humans. *Psychopharm (Berlin), 166,* 86–90.

Bellisle, F. (2004). Effects of diet on behavior and cognition in children. *British Journal of Nutrition, 92 (2),* 227-232.

Best, J.R., Miller, P.H. y Jones, L.L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review, 29,* 180-200.

Bell, J.G., MacKinlay, E.E., Dick, J.R., MacDonald, D.J., Boyle, R.M. y Glen, A.C.A. (2004). Essential fatty acids and phospholilpase A2 in autistic spectrum disorders. *Prostaglandins, Leukotrienes and Essential Fatty Acids, 71,* 201-204.

Birch, E., Carlson, S., Hoffman, D.R., Fitzgerald-Gustafson, K., Fu, V., Drover, J.R., Castañeda, Y., Minns, L., Wheaton, D., Mundy, D., Marunycz, J.y Diersen-Schade, D. (2010). The DIAMOND (DHA intake And Measurement OF Neural Development) Study: a double-masked, randomized controlled clinical trial of the maturation of infant visual acuity as a function of the dietary level of docosahexaenoic acid. *The Americal Journal of Clincial Nutrition, 91,* 848-858.

Branca, F. (2006). Nutritional solutions to major health problems of preschool children: How to optimize growth and development. *Journal of Pediatric Gastroenterology and Nutrition,43,* s4-s7.

Brocki, K.C., y Bohlin G. (2004). Executive functions in children aged 6–13: A dimensional and developmental study. *Developmental Neuropsychology, 26,* 571–593.

Bryan, J., Osendarp, S., Hughes, D., Calvaresi, E., Baghurst, K. y van Klinken, J. (2004). Nutrients for cognitive development in school-aged children. *Nutrition Reviews. 62,*(8), 295-306.

Bryce, J., Coitinho, D., Darnton-Hill, I., Pelletier, D y Pinstrup-Andersen P. (2008). Maternal and Child Undernutrition: effective action at national level. *Lancet, 371,* 510-526.

Caballero, B. (2005). A nutrition paradox: Underweight and obesity in developing countries. *The New England Journal of Medicine 352,* 1514-1517.

Caster, W.O., Andrews, J. W., Mohrhauer, H. y Holman, R. T. (1976). Effect of essential and nonessential fatty acids in complex mixture on fatty acid composition of liver lipids. *The Journal of Nutrition, 106,* 1809-1816.

Castro-González, M.A., Ojeda, A., Silencio, J.L., Cassis, L., Ledesma, H. y Pérez-Gil F. (2004). Perfil lípidico de 25 pescados marinos mexicanos con especial énfasis en sus ácidos grasos n-3 como componentes nutracéuticos. *Archivos Latinoamericanos de Nutrición, 54,*328-336.

Cattell, R. B. y Cattell, A. K. S. (2001). Factor "G" Escalas 2 y 3. 10^{th} ed. Madrid: Edicones Tea.

Caulfield, L.E., de Onis, M., Blössner, M. y Black, R. E. (2004). Undernutrition as an underlying cause of child deaths associated with diarrhea, pneumonia, malaria and measless. American Journal of Clinical Nutrition, 80, *193-198.*

Centers for Disease Control and Prevention (CDC). (2000). Percentile Data Files with LMS Values [document on the Internet]. CDC National Center for Health Stadistics [updated2009 August 4; cited 2009 September 30]. Available from: http://www.cdc.gov/growthcharts/percentile_data_files.htm

II Conteo de Población y Vivienda 2005. (2008). Proyecto IRIS-SCINCE II. [CD-ROM]. México: Instituto Nacional de Estadística y Geografía (INEGI).

Comité Internacional para el Desarrollo y Estudio del Cuestionario para Escolares y Adolescentes Latinoamericanos con Trastorno por Déficit de Atención con Hiperactividad (CEAL-TDAH). (2009). Cuestionario para Escolares y Adolescentes. Latinoamericanos con Trastorno por Déficit de Atención con Hiperactividad. Construcción, descripción del instrumento y datos sociodemográficos de la muestra. *Salud Mental, 32 (Supl 1*), 55-62.

Cheatham, C.L., Nerhammer, S., Asserhoj, M. Michaelsen, K., & Lauritzen, L. (2011) Effect of long- chain polyunsaturated fatty acid maternal supplementation during lactation on the executive function abilities of 7-year-olds. *Lipids* 46, 637-645.

Clearly, M.J. y Scott, A.J.(2011). Developments in clinical neuropsychology: implications for school psychological services. *Journal of School Health, 81*, 1-7.

Crone, E.A. (2009). Executive functions in adolescence: interferences from brain and behavior. *Developmental Science, 12(6),* 825-830.

Cserjési, R., Molnár, D., Luminet, O. y Lénárad, L. (2007). Is there any relationship between obesity and metal flexibility in children?. *Appetite, 49,* 675-678.

Dougherty, D.M., Bjork, J.M., Harper, R.A., Marsh, D., Moeller, F. G., Mathias, C.W. y Swann, A. (2003). Behavioral impulsivity paradigms: a comparison in hospitalized adolescents with disruptive behavior disorder. *Journal of Child Psychology and Psychiatry.44,*1145-1157.

Dennis, M., Agostino, A., Roncadin, C. y Levin, H. (2009). Theory of mind depends on domain-general executive functions of working memory and cognitive inhibition in children with traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology,32 (7)*835-847.

Falkingham, M., Abdelhamid, A., Curtis, P., Fairweather-Tait, S., Dye, Louise. Y Hooper L. (2010).The effects of oral iron supplementation on cognition in older children and adults: a systematic review and meta-analysis. *Nutrition Journal, 9, 4,* doi: 10.1186/1475-2891-9-4.

Fanjiang, G. Y Kleinman, R. (2007). Nutrition and performance in chidren, *Current Oponion in Clinical Nutrition and Metabolic Care, 10,* 342-347.

Fisk, J.E. y Sharp, C.A. (2004). Age-related impairment in Executive Functioning: Updating, inhibition, shifting and access. *Journal of Clinical and Experimental Neuropsychology, 26,* 874-890.

Fondo de las Naciones Unidas para la Infancia (UNICEF). (2009). Seguimiento de los progresos en nutrición de los niños y madres. Estados Unidos: Fondo de las Naciones Unidas para la Infancia.

Foley, J., García, J., Shaw, L. y Colden C. (2009). IQ predicts neuropsychological performance in children. *International Journal of Neuroscience, 119 (10),* 1830-1847.

Fondo de las Naciones Unidas para la Infancia (UNICEF). Seguimiento de los progresos en la nutrición de los niños y las madres: una prioridad en materia de supervivencia y desarrollo. Nueva York (NY): Fondo de las Naciones Unidas para la infancia, 2009.

Food and Agriculture Organization (FAO). (2008). El estado de la inseguridad alimentaria en el mundo. Italia: Organización de las Naciones Unidas para la Agricultura y la Alimentación.

Food and Agriculture Organization (FAO). (2010). El estado de la inseguridad alimentaria en el mundo. Italia: Organización de las Naciones Unidas para la Agricultura y la Alimentación.

Food and Agriculture Organization/World Health Organization (1992). World Declaration and Plan of Action for Nutrition. Rome: FAO.

Gadoth, N. (2008). On fish oil and omega-3 supplementation in children: The role of such supplementation on attention and cognitive dysfunction. *Brain & Development, 30,* 309-312.

García, E. M., Padrón, R. J., Ortiz-Hernández, L., Camacho, R. M. y Vargas, O. R. (2005). Efecto de la desnutrición *sobre* el desempeño académico de escolares. *Revista Mexicana de Pediatría, 72(3),* 117-125.

García-García, E., De la Llata-Romero, M., Kaufer-Horwintz, M., Tusié-Luna, M.T., Calzada-León, R., Vázquez-Velázquez, V., Barquera-Cervera, S., Caballero-Romo, A.J., Orozco, L., Velásquez-Fernández, D., Rosas-Peralta, M., Barriguete-Meléndez, A., Zacarías-Castillo, R. y Sotelo-Morales, J. (2008). La obesidad y el síndrome metabólico como problema de salud pública. Una reflexión. *Salud Pública de México*, *50(6),* 530-547.

Gale C. (2005). Height and intelligence. *International Journal of Epidemiology, 34,* 678-679.

Gale, C., Martyn,C., Marriott, L., Limond, J., Crozier, S., Inskip, H., Godfrey,K., Law, C., Cooper, C., Robinson, S. the Southampton Women's Survey Study Group. (2009). Dietary patterns in infancy and cognitive and neuropsychological function in childhood. *The Journal of Child Psychology and Psychiatry, 50 (7),* 816-823.

Garofalo, N., Gómez, A., Vargas, J. y Novoa, L. (2009). Repercusión de la nutrición en el neurodesarrollo y salud neuropsiquiátrica de niños y adolescentes. *Revista Cubana de Pediatría [online] ,81 (2) 0-0.*

Golden, C. J. (2005). *Stroop, Test de Colores y Palabras* (4ª ed.) Madrid: Ediciones Tea.

González-Castell, D., González-Cossio, T., Barquera, S. y Rivera, J.A. (2007). Alimentos industrializados en la dieta de los preescolares mexicanos. *Salud Pública de México, 49 (5),* 345-356.

Gordon, R.C., Rose, M.C., Skeaff, S.A., Gray, A.R., Morgan, K.M.D. y Ruffman, T. (2009). Iodine supplementation improves cognition in mildly iodine-deficient children. *The American Journal of Clinical Nutrition, 90,1*264-1271.

Grantham-McGregor, S. (2005). Can the provision of breakfast benefit school performance? *Food and Nutriton Buletin, 26 (2),* s144-158.

Grantham-McGregor, S., Cheung, Y.B., Cueto, S.,Glewwe, P., Richter, L., Strupp. B. y el International Child Development Sterring Grup. (2007). Developmental potential in the first 5 years for children in developing countries. *Lancet, 369,* 60-70.

Grantham-McCregor,S., Fernald, L. y Serthuraman, K. (1999). Effects of health and nutrition on cognitive and behavioral development in children in the first three years of life. 2. Infections and micronutrient deficiencies: Idoine, iron and zinc. *Food and Nutrition Bulletin, 20,* 76-99.

Gustafson, D.R. (2006). Obesity and intelligence. *Agro Food Industry Hi-Tech, 17 (5),* XXXI-XXXIV.

Gunstad, J., Spitznagel, M. B., Paul, R.H., Cohen, R.A., Kohn, M., Luyster, F.S., Clark, R.,Williams, L. M. y Gordon, E. (2008). Body mass index and neuropsychological function in healthy children and adolescents. *Appetite, 50,* 246-251.

Gustand, J., Paul, R.H., Cohen, R.A., Tate, D.F. y Gordon, E. (2006). Obesity is associated with memory deficits in young and middle-aged adults. *Eating and weight disorders, 11(1),* 15-19.

Guxens, M., Méndez, M.A., Julvez, J., Plana, E., Forns, .J, Basagaña, X., Torrent, M. y Sunyer, J. (2009). Cognitive Function and Overweight in Preschool Children. *American Journal of Epidemiology, 170,* 438-446.

Hamadani, J. D., Fuchs, G. J., Osendarp, S.J.M., Khatun, F., Huda, S.N. y Grantham-McGregor, S.M. (2001). Randomized controlled trial of the effect of zinc supplementation on the mental development of Bangladeshi infants. *American Journal of Clinical Nutrition, 74,* 381-386.

Hassing, L., Wahlin, A., Winblad, D. y Backman, L. (1999). Further evidence on the effects of vitamin B12 and folate levels on episodic memory functioning; a population-based study of healthy very old adults. *Biological Psychiatry, 45,*1472–1480.

Hernández, G., Orellana, G., Kimelman, M., Nuñez, C. e Ibáñez, C. (2005). Trastornos de ansiedad en pacientes hospitalizados en Medicina Interna. *Revista Médica de Chile, 133,* 895-902.

Hirayama, S., Hamazaki, T. Y Terasawa, K. (2004). Effect of docosahexaenoic acid-containing food administration on symptoms of attention-deficit/hyperactivity disorder- a placebo-controlled double-blind study. *European Journal of Clinical Nutrition, 58,* 467-473.

Hoyland, A., Dye, L. and Lawton, C.L. (2009). A systematic review of the effect of breakfast on the cognitive performance of children and adolescent. *Nutrition Research Reviews, 22,* 220-243.

Hubel, D.H. y Wiesel, T.N. The period of susceptibility to the physiological effects of unilateral eye closure in kittens. *Journal of Physiology, 206,* 419-436.

Huizinga, M., Dolan, C. y van der Molen, M. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia, 44,* 2017–2036.

Imdad, A., Sadig, K. y Bhutta, Z. (2011). Evidence-based prevention of childhood malnutrition. *Current opinion in clinical nutrition and metabolic care, 14 (3),* 276-285.

Innis, S. (2007). Fatty acids and early human development. *Erly Human Development, 83,* 761-766.

Iriart, C., Handal, A.J., Boursaw, B. y Rodrigues, G. (2011). Chronic Malnutrition Among Overweight Hispanic Children: Understanding Health Disparities. *Journal of Immigrant Minority Health,* DOI 10.1007/s10903-011-9464-7.

Ito, M. (2004). 'Nurturing the brian' as an emerging research field involving child neurology. *Brain & Developmet,26,* 429-433.

Ivanovic, R., Forno, H., Durán, M.C., Hazbún, J., Castro, C. e Ivanovic, D. (2000). Estudio de la capacidad intelectual (Test de Matrices Progresivas de Raven) en escolares de 5 a 18 años. Antecedentes generales, normas y recomendaciones. *Revista de Psicología General y Aplicada,53,*5-30.

Johnson, C.R., Handen, B. L., Zimmer, M. & Saco, K. (2010) Polyunsaturated Fatty Acid Supplementation in Young Children with Autism. *Journal of Developmental Physical Disabilities, 22,*1–10 DOI 10.1007/s10882-009-9152-x.

Johnson, M., Östlund, S., Fransson, G., Kadesjö, B. y Gillberg, Ch. (2009). Omega-3/Omega-6 fatty acids for Attention Deficit Hiperactivity Disorder: A randomized placebo-controlled trial in children and adolescents. *Journal of Attention Disorders, 12 (5),* 394-401.

Kakiraluloma, L., Närhi, V., Ahonen, T., Westerholm, J. y Aro, M. (2008). Do fatty acids helping overcoming reading difficulties? A double-blind, placebo-controlled study of the effects of eicosapentaenoic acid and carnosine supplementation on children with dyslexia. *Child: care, health and development, 35(1),* 112-119.

Kalkut, E.L., Han, S.D., Lansing, A.E., Holdnack, J.A. y Delis, D.C. (2009). Development of Set-Shifting ability from late childhood through early adulthood. *Archives of Clinical Neuropsychology,24,*565-574.

Kar, B.R., Rao, S. L. y Chandramouli, B.A. (2008). Cognitive development in children with chronic protein energy malnutrition. *Behavioral and Brain Functions, 4 (31)* doi:10.1186/1744-9081-4-31

Kellogg, C.E. y Morton, N.W. (2003). *Beta III.* México: Manual Moderno.

Kirby, A., Woodward, A., Jackson, S., Wang, M.A., Crawford, U. y Koizumi, H. (2004). A double-blind, placebo-controlled study investigating the effects of Omega-3 supplementation in children aged 8-10 years from a mainstream school population. *Research in Developmental Disabilities, 31,* 718-730.

Kirby, A., Woodward, A., Jackson, S. (2009). Benefits of omega-3 supplementation for schoolchildren: review of the current evidence. *British Educational Research Journal, 36 (5),* 699-732.

Klimkeit, E.L., Mattingley, J.B., Sheppard, D.M., Farrow, M. and Bradshaw, J.L. (2004). Examining the development of attention and executive functions in children with a novel paradigm. *Child Neuropsychology, 10,* 201-211.

Koizumi, H. (2004). The concept of 'developing the brain': a new natural science for learning and education. *Brain & Development, 26,* 434-441.

Koren, R., Kofman, O. y Berger, A. (2005). Analysis of word clustering in verbal fluency of school-aged children. *Archives of Clinical Neuropsychology, 20,* 1087-1104.

Kramer, M.S., Aboud, F., Mironova, E., Vanilovich, I., Platt, R.W., Matush, L., Igumnov, S., Fombonne, E., Bogdanovich, N., Ducruet, T., Collet, J.P., Chalmers, B., Hodnett, E., Davidovsky, S., Skugarevsky, O., Trofimovich, O., Kozlova, L., & Shapiro, S. (2008). Breastfeeding and child cognitive development: New evidence from a large randomized trial. Archives of General Psychiatry, 65, 578–584.

Leiner, M.A., Balcazar, H., Straus, D.C., Shirsat, P. y Handal,G. Screening Mexicans for psychosocial and behavioral problems during pediatric consultation.(2007). *Revista de Investigación Clínica, 59(2),* 116-123.

Liu, J., Raine, A., Venable, P.H. y Sarnoff, A. (2004). Malnutrition at 3 years and externalizing behavior problems at ages 8, 11 and 17 years. *American Journal of Psychiatry, 161,* 2005-2013.

López-Alvarenga, J.C., Vázquez-Velázquez,V., Bolado-García, V.E., González-Barranco, J., Castañeda-López, J., Robles, L., Velásquez-Alva, C., Aguirre-Hernández, R. y Comuzzie, A. (2007). Influencia de los padres sobre las preferencias alimentarias en niños de dos escuelas primarias con diferente estrato económico. Estudio ESFUERSO. *Gaceta Medica de México, 143*,(6), 463-469.

López-Soler, C., Alcántara, M.V., Fernández, V., Castro, M., López, J.A. (2010). Características y prevalencia de los problemas de ansiedad, depresión y quejas somáticas en una muestra clínica infantil de 8 a 12 años, mediante el CBCL (Child Behavior Cheklist). *Anales de Psicología, 26,* 325-334.

Lozoff, B., Jimenez, E., Hagen, J., Mollen, E. y Wolf, A.W. (2000). Poorer behavioral and developmental outcome more than 10 years after for iron deficiency in infancy. *Pediatrics,* 105 (4), E51.

Mahoney, C.R., Taylor, H.A., Kanarek, R.B. y Samuel, P. (2005). Effect of breakfast composition on cognitive processes in elementary school children. *Physiology & Behavior, 85,* 635–645.

Malecka-Tendera, E., y Mazur, A. (2006). Childhood obesity: a pandemic of the twenty-first century. *International Journal of Obesity, 30,* S1–S3.

Mataix, F. J. y Gil, A. (2004). Libro Blanco de los Omega-3. Los ácidos grasos poliinsaturados Omega 3 y monoinsaturados tipo oleico y su papel en la salud. (1era edición). España: Panamericana.

Matute, E., Rosselli, M., Ardila, A. y Ostrosky-Solís, F. (2007). *Evaluación Neuropsicológica Infantil (ENI).* México: Manual Moderno.

McLachlan, M. 2006. Tackling the child malnutrituion problem: From what and why to how much and how. *Journal of Pediatric Gastroenterology and Nutrituion, 43 (suppl 3),* 38 43.

McLaren, D.S. y Read W.W.C. (1975). Weight/length classification of nutritional status. *Lacent, 2,* 219-221.

Mendez, M. A. y Adair, L.S. (1999). Severity and timing of stunting in the first two years of life affect performance on cognitive test in late childhood. *Journal of Nutrition, 129,* 1555-1562.

Menezes-Filho J. A., Novaes C. O., Moreira, J. C., Sarcinelli, P. N. y Mergler, D. (2011). Elevated manganese and cognitive performance in school-age children and their mothers. *Environmental Research, 111,* 156-163.

Mond, J.M., Stich, H., Hay, P.J., Kraemer, A. y Baune, B.T. (2007). Associations between obesity and developmental functioning in pre-school children: a population-based study. *International Journal of Obesity, 31,* 1068-1073.

Muthayya, S., Eilander, A., Transler, C., Thomas, T., van der Knaap, H., Srinivasan, K., van Klinken, B., Osendarp, S. y Kurpad, A. (2009). Effect of fortification with multiple micronutrients and n-3 fatty acids on growth and cognitive performance in Indian schoolchildren: the CHAMPION (children´s Health and Mental Performance Influenced by Optimal Nutrition) Study. *The American Journal of Clinical Nutrition, 89,* 1766-1775.

Navarro-Hernández, Q. y Navarro-Jiménez, R. (2002). Evaluación de la relación entre el estado nutricio e índice de coeficientee intelectual en niños escolares. *Revista de la Facultad de medicina, 45*, 204-207.

Neumann, C.G., Murphy, S.P., Gewa, C., Grillenberger, M. y Bwibo, N.O. (2007). Meat supplementation improves growth, cognitive, and behavioral outcomes in Kenyan children. *Journal of Nutrition, 137,* 1119-1123.

Nigg, J.T., Quamma, J.P., Greenberg, M.T. y Kusche, C.A. (1999). A how-year longitudinal study of neuropsychological and cognitive performance in relation to behavioural problems and competencies in elementary school children. *Journal of Abnormal Psychology, 27(1),* 51-63.

Novak, E.M., Dyer, R.A e Innis, S.M. (2008). High dietary omega-6 acids contribute to reduced docasahexaenoic acid in the developing brain and inhibit secondary neurite growth. *Brain Research,1237,* 136-145.

Nyberg, L., Brocki, K., Tillman, C. y Bohlin, G. (2009). The proposed interaction between working memory and inhibition. *European Journal of Cognitive Psychology, 21(1),* 84-111.

Oddy, W.H., Robinson, M., Amrosini, G.L., O´Sullivan, T.A., de Klerk, N.H., Beilin, L.J., Silburn, S.R., Zubrick, S.R. y Stanley, F.J.(2009). The association between dietary patterns and mental health in early adolescence. *Preventive Medicine, 4 (1),* 39-44.

Olaiz, G., Rivera, J., Shamah, T., Rojas, R., Villalpando, S., Hernández, M. y Sepúlveda, J. (2006). Encuesta Nacional de Salud y Nutrición, 2006 (ENSANULT, 2006). México: Instituto Nacional de Salud Pública.

Ortiz, L. y Ramos, N. (2008). Nutrición y alimentación de los niños y adolescentes mexicanos. Primera parte: Deficiencias nutrimentales. *Revista Mexicana de Pediatría, 75(4),* 175-180.

Perales, 2003 cited by Verdejo-García, A., Bechara, A., Recknor, E.C. y Pérez-García, M. (2006). Frontal behavioral deficits in substance dependent individuals during drugs use and during abstinence: An examination of the behavioral, cognitive and emotional correlates of addiction. *Journal of the International Neuropsychology,12,* 405-415.

Plan de desarrollo Urbano (PDU). (2010). Ciudad Juárez, México: Instituto Municipal de Investigación y Planeación (IMIP).

Raz, R., Carasso, R.L. & Yehuda, S. (2009). The influence of short-chain Essential Fatty Acid on children with Attention-Deficit/Hyperactivity Disorder: A doble-blind placebo-controlled study. *Journal of Child and Adolescent Psychopharmacology, 19,* (2), 167-177.

Raz, R. y Gabis, L. (2009). Essential fatty acids and attention-deficit–hyperactivity disorder: a systematic review. *Developmental Medicine & Child Neurology, 51(8),* 580-595.

Reitan, R.M. (1958). Validity of the Trail Making Test as an indicator of organic brain damage. *Perceptual and Motor Skills, 8,* 271-276.

Rey, A. (1987). *Test de Copia de la Figura Compleja (Rey).* Madrid: Ediciones TEA.

Richards, M., Hardy, R., Kuh, D. y Wadsworth, M. (2002). Birth weight, postnatal growth and cognitive function in a national UK birth cohort. *International Journal of Epidemiology, 31 (2),* 342-348.

Richardson, A.J. y Montgomery P. (2005). The Oxford-Durham Study: A randomize, controlled trial of dietary supplementation with fatty acids in children with Developmental Coordination Disorder. *Pediatrics, 115 (5),* 1360-1366.

Richardson, A.J y Puri, B.K (2002). A randomized double-blind, placebo-controlled study of the effects of supplementation with highly unsaturated fatty acids on ADHD-related symptoms in children with specific learning difficulties. *Progress in Neuro-Psychopharmacology & Biological Psychiatry, 26,* 233-239.

Richardson, A. J. y Ross, M.A. (2000). Fatty acid metabolism in neurodevelopmental disorder: a new perspective on associations between attention-deficit/hyperactivity disorder, dyslexia, dyspraxia and the autistic spectrum. *Prostaglandins Leukot Essent Fatty Acids; 63,* 1-9.

Rico, J.A., Kordas, K., López, P., Rosado, J.L., Vargas, G.G., Ronquillo, D. y Stoltzfus, R, J. (2006). Efficacy of iron and/or zinc supplementation on cognitive performance of lead-exposed Mexican schoolchildren: a randomized, placebo controlled trial. *Pediatrics, 117,* 518-527.

Rivera- Dommarco, J., Cuevas-Nasu, L., Shamah-Levy ,T., Villalpando-Hernández, S., Ávila-Arcos, M.A. y Jimenez-Aguilar, A. Estado nutricio. En: Olaiz-Fernández G, Rivera-Dommarco J, Shamah-Levy T, Rojas R, Villalpando-Hernández S, Hernández-Avila M. y Sepúlveda-Amor, J. (2006). Encuesta Nacional de Salud y Nutrición 2006. Cuernavaca, México: Instituto Nacional de Salud Pública, 2006: 85-103.

Rivera, J. A. y Sepúlveda, J. (2003). Conclusions from the Mexican National Nutrition Survey 1999: translating results into nutrition policy. *Salud Pública de México, 45,* s565- s575.

Romine, C. B. y Reynolds, C. R. (2004). Sequential Memory: A developmental perspective on its relation to frontal lobe functioning. *Neuropsychology Review, 14(1),* 43-64.

SAGAR. (1995). *Programa agropecuario y de desarrollo rural 1995-2000.* En Decreto. México.

Sánchez-Castillo, P., Pichardo-Ontiveros, E. y López-R, P. (2004). Epidemiología de la obesidad. *Gaceta Médica de México, 140, (supl 2),*3-20.

Schachar, R. y Logan, G.D. (1990). Impulsivity and inhibitory control in normal developmental. *Developmental Psycholology, 26 (5),* 710-720.

Sinn, N. y Bryan, J. (2007). Effects of supplementation with polyunsaturated fatty acids and micronutrients on learning and behavior problems associated with child ADHD. *Journal of Developmental & Behavioral Pediatrics,28,* 82-91.

Sigfúsdóttir, I, D., Kristjánsson, A.L. y Allegrante, J. P. (2007). Health behavior and academic achievement in Icelandic school children. *Health Education Research, 22(1),* 70-80.

Simopoulos,A.P. (2002). The importance of the ratio of omega-6/omega-3 essential fatty acids. *Biomed Pharmacotherapy, 56,* 365-379.

Surette, M. (2008). The science behind dietary omega-3 fatty acids. *Canadian Medical Association Journal, 178 (2),* 177-180.

Taras, H. (2005). Nutrition and student performance at school. *Journal of School Healt,75 (6),* 199-213.

Taras, H. y Potts-Datema, W. (2005). Obesity and student performance at school. *Journal of School Health, 75,* 291–295.

Themane, M.J., Monyeki, K.D., Nthangeni, H.C., Kemper, G. y Twisk J.W.R. (2003). The relationship between health (malnutrition) and educational achievements (Maths and English) in the rural children of South Africa. *International Journal of Educational Development, 23,* 637-643.

Thurstone, L..L. y Thurstone, T. G. (2004). Test de Aptitudes Escolares 1 (TEA.1). 11th ed. Madrid: Tea Editions.

Tofail, F., Persson, L.A., Arifeen, S. E., Hamandani, J. D., Mehrin, F., Ridout, D., Ekstöm, E., Huda, S. N. & Grantham-McGregor, S.M. (2008). Effects of prenatal food and micronutrient supplementation on infant development: a randomized trial from the

Maternal and Infant Nutrition Intervention, Matlab (MINIMat) study. *American Journal of Clinical Nutrition,87,* 704-711.

Uauy, R. y Mena, P. (2001). Lipids and neurodevelopment. *Nutrition Reviews; 59 (8).* s34-s48.

US Department of Education (2001). The Elementary and Secondary Education Act: PL 107-110, the No Child Left Behind Act of 2001. Available at: http://www.ed.gov/policy/elsec/leg/esea02/index.html. Accessed June 16, 2011.

Valencia, N.J., Laserna, J.A., Pérez-García, M, Orozco, C., Miñán, M., Garrido, C., Peralta, M.I. y Morente, G. (2000). et al. Influencia de la escolaridad y el sexo sobre la ejecución en el FAS, nombrar animales y nombrar frutas. *Psicología Conductual,8,* 283-295.

Verdejo-García, A. y Pérez-García, M. (2007). Profiles of executive deficits in cocaine and heroin polysubstance user: common and differential effects on separate executive components. *Psychopharmacology, 190,* 517-530.

Verdejo-García A, Pérez-Exposito M, Schmidt-Rio-Valle J, Fernández-Serrano, M. J., Cruz, F., Pérez-García, M., López-Bemonte, G., Martín-Matillas, M., Martín-Lagos, J.A. y Campoy C. (2010). Selective Alterations Within Executive Functions in Adolescents With Excess Weigh. Obesity, published online Jan 7. doi:10.1038/oby.2009.475

Wachs, T. (2000). Nutritional deficits and behavioral development. *International Journal of Behavioral Development, 24 (4),* 435-441.

Walker, S. P., Chang, S. M., Powell, C. A. y Mgrantham-McGregor, S. (2005). Effects of early childhood psychosocial stimulation and nutritional supplementation on cognition and education in growth-stunted Jamaican children: prospective cohort study. *Lancet, 366,* 1804-1807.

Wang, F. y Veugelers, P. J. (2008). Self-esteem and cognitive development in the era of the childhood obesity epidemic. *Obesity Reviews, 9,* 615-623.

Waterlow, J.C. (1972). Classification and definition of protein calorie malnutrition. *British Medical Journal, 3,* 566-569.

Wechsler, D. (2007). *Escala de inteligencia de Wechsler para Niños-IV (WISC-IV).* México: Manual Moderno.

Wesnes, K.A., Pincock, C., Richardson, D., Helm, G. y Hails, S. (2003). Breakfast reduces declines in attention and memory over the morning in school children. *Appetite, 41,* 329–331.

Williams, B.R., Ponesse, J.S., Schachar, R.J., Logan, G.D. y Tannock, R. (1999). Developmental of inhibitory control across the life span. *Developmental Psychology, 35 (1),* 205-213.

Yehuda, S., Rabinovitz, S. y Mostofsky, D.I. (2005). Mixture of essential fatty acids lowers test anxiety. *Nutritional Neuroscience, 8*,(4), 265-267.

Yehuda, S., Rabinovitz, S. y Mostofsky, D.I. (2006). Nutritional deficiencies in learning and cognition. *Journal of Pediatric Gastroenterology and Nutrition, 43,* s22-s25.

Yeduha, S., Rabionovitz, S. y Mostofsky, D.I. (1999). Essential fatty acids are mediators of brain biochemistry and cognitive functions. *Journal of Neuroscience Research, 56,* 565-570.

Yehuda, S., Rabionovitz, S., Carrasso, R. L y Mostofsky, D.I. (2002). The role of polyunsaturated fatty acids in restoring the aging neuronal membrane. *Neurobiology of aging, 23,* 843-853.

Youdim, K.A., Martin, A. y Joseph, J.A. (2000). Essential fatty acids and the brain: possible health implications. *International Journal of Developmental Neuroscience, 18,* 383-399.

Zimmermann, M. B., Connolly, K., Bozo, M., Bridson, J., Rohner, F. y Grimci, L. (2006). Iodine supplementation improves cognition in iodine-deficient schoolchildren in Albania: a randomized, controlled, double-blind study. *American Journal of Clinical Nutrition, 83,* 108-114.

Zlotkin, S. 2006. Priorities in nutritional rehabilitation. *Journal of Pediatric Gastroenterology and Nutrition, 43,* s66-s71.

ANEXOS

Anexo I

Low non verbal intelligence and academic skills in Mexican obese children versus malnourished.

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Abstract

Objective: To investigate how altered nutritional status (malnutrition and obesity) affects both the intellectual performance and academic abilities of children between 8 to 9 years. Method: A total of 98 children (35 malnourished, 31 normal nutrition and 32 obese) were evaluated in two areas: cognition and academic abilities. Results: The analysis of variance shows statistical differences in the G Factor based on the direct scoring, resulting lower scores in the obese children group than in those in the malnutrition and normal nutrition group. In verbal skills no significant differences in the three groups were found. In obesity intellectual performance ratings were lower than normal and malnourished. Conclusion: The results showed that obese children have diminished, intellectual performance and academic abilities rather than children with low to moderate malnutrition.

Keywords. Obesity; Malnutrition: Academic abilities; Intellectual performance; Children

Introduction

Child obesity has also increased substantially in recent decades and is now considered an epidemic[1] and in some cases, even a pandemic, [2] especially in Latin America.[3] This trend of obesity is particularly prevalent in Mexico. According to published data from the National Survey of Health and Nutrition (ENSANUT, 2006),[4] the prevalence of overweight and obese children of ages 5 to 11 in Mexico, using the criteria of the International Obesity Taskforce (IOTF), was around 26% for both sexes. Also northern Mexico had the greater prevalence of obese children.[5]

However, currently obesity and malnutrition are one of the biggest crises in developing countries because they are occurring simultaneously.[6] This problem may be related to a significant pattern of poor eating habits. Data in Mexico indicated that the proportion of school-age children and adolescents who eat fish, fruits and vegetables, is low, while those who routinely consumed energy-dense foods and low nutrient density foods such as soft drinks, sweets, salted snacks and shortbreads, is high.[7] Therefore the coexistence of obesity and malnutrition, has introduced a previously atypical situation which, in turns, produces a double disadvantage.[8]

In the past 50 years there have been several nutrition and child studies published that have clearly showed the negative impact of malnutrition on cognition, behavior, and physical performance.[9] Walker, Chang, Powell and Mgrantham-McGregor,[10] found that the effects of malnutrition on educational and cognitive activities in children during early childhood, continues into late adolescence. García et al.,[11] found that malnutritioned Mexican children between the 3rd and 4th year of elementary school were found to have low birth weight and low height for their age, which are signs of malnutrition, and they were more likely to repeat school years. Similar results were found in a study that investigated the relationship between nutritional status and IQ showing that a nutritional deficiency leads to a lower intellectual level in both obese and malnourished children, this study was conducted with 203 Mexican children between 6 and 13 years.[12] When food insufficiency was used rather than malnutrition results showed that children between 6 to 11 years had a significant decrease in mathematical, reading, cube design and working memory abilities compared to a control group.[13]

Obesity is also believed to be associated with cognitive deficits, but the research is inconclusive and methodologically problematic.[14] For example, studies have found that higher body mass index (BMI) is associated with poor cognitive function in children.[15] However, in another study Gunstad et al.,[16] reported no relationship between high BMI and cognitive dysfunction in healthy children. Also a longitudinal study reported no association between weight and verbal intelligence.[17] Cserjési et al.,[18] reported no differences in working memory and abstract reasoning (measured with arrays) or semantic verbal function and Verdejo-García et al.,[19] reported no differences in decision making process. In contrast, other studies found an association between obesity and decreased academic performance in children, affecting girls more than boys.[20] In general, obesity has been linked with decreased academic performance.

However, no direct comparisons between obese and malnutrition of children had been conducted so far, in terms of intellectual or academic performance, to compare the relevance of former deficits in such a nutritional problems. To know the type and frequency of intellectual and academic potential differences could be important to establish specific resources in order to support these children. As mentioned, research findings on this topic have been inconclusive,[14] the lack of appropriate and standard measurement of suspected deficits has been cause of such findings.[21] In essence, whereas there is a clinical evidence to suggest a link between maladaptive eating patterns during childhood and subsequent cognitive deficits according to the literature as it presently stands is inconclusive, at best, is problematic, at worst.

Therefore, the purpose of this study was to investigate how malnutrition and obesity affect both fluid intelligence and academic performance of Spanish speaking children between 8 to 9 years of age. Of additional interest is the use of such tests while controlling variables such as socioeconomic status, culture, and intelligence of the mothers as these variables may modulate the potential effect associated with the presence of both malnutrition and obesity. It was hypothesized that malnutrition and obesity are linked with low cognitive and academic performance.

Method

This study was conducted in two schools in Ciudad Juarez, in the state of Chihuahua in Mexico. A total of 98 children between 8 to 9 years old (*M*= 8.38, SD= 0.49), (46 boys and 52 girls) who were enrolled in the third or fourth grade were recruited. Of the sample, 35 children were malnouriched (MG), 31 were in normal nutritional status (control group) (NNG) and 32 were obese (OG).

The socioeconomic status of the participants in the sample was low, and all resided in urban locales. Participants were recruited from a low socio-economic area of Ciudad Juarez, Mexico. SES was based on the II Conteo de Población y Vivienda, (2005)[22] based on data such illiteracy, number of individuals living per room, etc. The criteria used was as follows; 1.Very low SES. 2. Low SES. 3. Mid SES 4. High SES 5. Very high SES. According to the Plan de Desarrollo Urbano (PDU) (2010)[23] of the Ciudad Juarez, the two neighborhoods used for the study residents are of the Low SES group. Exclusion criteria were the history and/or presence of neurological diseases (e.g., epilepsy, traumatic brain injury, or other neurological syndromes) and hormonal diseases (diabetes or thyroid-related diseases). The demographics and clinical characteristics of the sample can be seen in Table 1.

The children's parents were fully informed of the study prior to their participation and, if agreed, their consent was obtained. This project, including the informed consent, was approved by the bioethics committee of the Autonomous University of Ciudad Juarez (UACJ).

Materials

Anthropometrics Measurements

Core measures were identified (weight and height) and anthropometric index taken (McLaren index, percentages of weight/age height/age and weight/height). The anthropometric measurements were obtained according to the specifications manual of anthropometry of the National Council for Science and Technology (CONACYT).[24]

The weight was determined by a Seca ® electronic scale. The size was measured in a standing position, with the head placed so that the plan of Frankfurt was at the horizontal position, a Harpenden stadimeter was used to get these measurements. All participants were wearing school uniforms (skirt and shirt for girls and pants and shirt for boys) and no shoes during the anthropometric data collection phase. The reference standards for weight and height were the curves and growth tables of the Center for Diseases Control (CDC).[25] in 2000. For the classification of nutritional status cut-off points were used in the standings from McLaren & Read[26] (1975) and Waterlow[27] (1972).

Cognitive Measures

Measures used with the children. Factor "G" of Catell[28] (2001), was administered. This test measure fluid intelligence and is divided into 4 tasks (Series, Classification, Progressive Matrices and Topological Conditions). The total scores are converted into IQ scores.

Academic abilities.

Measures used with the children. Scholars Aptitude Test (TEA-1)[29] was administered. This test has 5 subtests (drawings, different word, vocabulary, reasoning and calculus) which evaluate three aptitude dimensions: verbal, reasoning and calculation, which can produce an IQ score.

Measures used with the mothers. The Beta III[30] was administered to the mothers after completion of informed consent. This test measures non verbal intelligence, processing information, processing speed, spatial reasoning, non verbal reasoning and aspects of fluid intelligence. This test has 6 subtest (figure completion, digits, associated pairs, object assembly, and matrices).The subtests then provides a composite IQ.

Procedure

Two schools from a low socio-economic area of Ciudad Juarez participated in the project. A meeting was held and parents were informed about the project. An informed consent was given to the parents that showed interested in participating in the study. The mothers then completed the Beta III[30] intelligence test as well as completed a demographic questionnaire about their children. During the following days the children anthropometric measurements were taken to determine their nutritional conditions.

Once the sample classification based on their nutrition was obtained, the two IQ tests and TEA-1 tests[29] were given in groups of 10 in morning during school hours. The test was administered by three trained psychometricians (one professional and two students in their last semester of psychology training) in the two selected school.

Variables and statistical analysis

The grouping variable or independent was the nutritional status which was divided into three groups: obese (OG), normal nutrition (NNG) and malnourished (MG). The cut off points MG was 85-95% in height/age and 70-90% in weight/age, for the NNG was 95-105% and 90-110% respectively and for OG was up 120% in both.[27]

The dependent variables to measure the IQ scores were used directly for the four subscales of Factor G:[28]

Series (Se): Score direct series subtest.

Classification (Cl): Score direct classification subtest.

Progressive Matrices (PM): Score direct t matrices subtest.

Topological Conditions (TC): Score direct subtest topological conditions.

Total Direct Score (Tot DS). The sum of the direct scoring of the four subscales: series, classification, progressive matrices and topological conditions.

The direct test scores were used as the academic performance variables. The following are the tests used:

Drawings (Dw) directly in the subtest scores of drawings.

Different words (Dif Word): direct score in the subtest of different words.

Vocabulary (Voc): direct score in the vocabulary subtest.

Reasoning (Ra): Direct score reasoning subtest.

Calculus (Ca) directly in the subtest score calculation.

Total Verbal (Tot Ver): sum of scores on the subtest direct designs, different words and vocabulary.

Total Non-verbal direct (Tot NV): sum of the scores in the subtest of reasoning and drawings. Total Global (Tot G): Total of scores in the subtest direct designs, different words, vocabulary, reasoning and calculation.

Intellectual Coefficient (IQ): The global intellectual coefficient.

In order to study the differences among the groups, a multivariate analysis of variance (MANOVA) was done using a diagnostic group as the independent variable (OG vs. NNG vs. MG). The scores on the psychological tests were used as dependent variable. An ANOVA was conducted. Post hoc comparisons and Scheffe test were conducted after the ANOVA. Statistical associations among variables were studied using the Pearson Correlation Test.

Results

Groups were equally distributed according to the demographic variables of the children and their mothers. Results showed that there was no statistically significant difference in the age of the children; IQ, academic level or economic status of the mothers. However, differences were found in the percentage of boys and girls in each group, which is congruent with the prevalence differences of these disorders between boys and girls[4] (see Table 1).

In order to evaluate if the gender variable affects the IQ measures and academic performance, an ANOVA analysis was performed and results showed that there were no significant difference between boys and girls regarding IQ and academic performance. Therefore, gender was not considered in the next analysis.

A, possible differences between groups in IQ scores was pursued. The results showed that there were significant differences for the four Factor G subtests [Lambda (8,184) = 0.812, p<=0.012]. Further univariate ANOVAS showed that the PM subtest [F (2.95) = 5,503, p <0.005], TC [F (2,95) = 3'194, P <0.005],and Tot DS [F (2,95) = 4'070, P <0.005], in the obese group was significantly lower than the OG and MG (see Table 2).

Possible differences between groups in academic performance scores were then explored. The results showed that significant differences existed for the Dw subtest [F (2.95) = 4,526, P <0.013], with the obese group being significantly lower than MG and NNG (See Table 3).

Finally, the relationship between IQ scores of each group and academic abilities was considered. Results showed moderately high direct correlations of the subtests Progressive Matrices, Topological Conditions and overall G-factor scales with academic abilities performance in the three groups (See Table 4).

Discussion

The purpose of this study was to compare intellectual abilities and academic performance of Spanish speaking obese and malnutritioned children, between 8 to 9 years. The results showed that obese children had lower performance in fluid intelligence and nonverbal academic skills than mild to moderate malnourished children. Also, moderately high direct correlations of the progressive matrices subtest with academic skills have been found.

Our results showed that obesity affect the intellectual and academic skills more than mild to moderate malnourishment. In fact, latter condition showed the same performance than the control group. According with these results, obese children could require more support during scholarship. On the other hand, no significant differences were found in the IQ of the mothers, years of schooling, and age of the mothers. As children of the same area and lower-middle socioeconomic status the differences found in IQ cannot be explained by socioeconomic status. The only similar study was carried out by Navarro-Hernández and Navarro-Jiménez,[12] the results of this study are consistent with the present study in that they support the hypothesis that nutritional alterations are associated with decreased intellectual performance, but the Navarro-Hernández and Navarro-Jiménez[12] study used only an infrequently used and somewhat subjective IQ test, the Goodenough.

The present study supports previous studies that investigated obesity and malnourishment in children.[18] In contrast with Gunstad et al.,[16] the present study did find significant differences between obese and control groups, in fluid intelligence, specifically in Progressive Matrices and Topological Conditions. Nevertheless no differences in verbal abilities were found, as previously mentioned by Richards et al. [17]

Some prior studies found that obesity is associated with a decreased academic performance in children, particularly in girls[20] whereas, Azurmendi et al.,[31] did not find differences between gender. The present studies are supportive of Zlotkin[6] and Caballero[32] in that obesity and malnutrition in children of low socioeconomic status may be associated with the particular characteristics of Ciudad Juarez. Specifically border cities in Mexico are fraught with poverty, crime and unstable socio-economic circumstances.[6,7]

Some limitations of the present study should be considered. The three major ones include 1) only a limited range of socioeconomic standards were included. 2) Severe malnourished states were not included. 3) Finally, the length of the nutritional status of the participants is not known. Replications of these findings in other Spanish speaking countries, or other non-English speaking developing countries may allow for greater generalizability of the relationship of previously published studies.

In summary, IQ was related to the academic performance of the children and such cognitive performance was linked to obesity more than malnutrition. This is congruent with previous studies that have found such a relationship,[33] but it extends previous findings by controlling important variables such as mother's intelligence and children's socio-economic status. However, despite these findings further study attempting to understand how malnutrition and obesity, combined and alone, affect subsequent cognitive functioning is cleared needed.

References

1. Sigfúsdóttir ID, Kristjánsson AL, Allegrante JP. Health behavior and academic achievement in Icelandic school children. *Health Educ Res* 2007; 22: 70-80.

2. Malecka-Tendera E, Mazur A. Childhood obesity: a pandemic of the twenty-first century. *Int J Obes* 2006; 30: S1–S3.

3. Amigo H. Obesidad en el niño en América Latina: situación, criterios de diagnóstico y desafíos. *Cad Saúde Pública* 2003; 19(Suppl 1): 163-170.

4. Olaiz G, Rivera J, Shamah T, et al. Encuesta Nacional de Salud y Nutrición 2006 (ENSANULT). México: Instituto Nacional de Salud Pública 2006.

5. Bacardí-Gascón M, Jiménez-Cruz A, Jones E, et al. Alta prevalencia de obesidad y obesidad abdominal en niños escolares entre 6 y 12 años de edad. *Bol Med Hosp Infant Mex* 2007; 64: 362-369.

6. Zlotkin S. Priorities in nutritional rehabilitation. *J Pediatr Gastroenterol Nutr* 2006; 43: s66-s71.

7. Ortiz L, Ramos N. Nutrición y alimentación de los niños y adolescentes mexicanos. Primera parte: Deficiencias nutrimentales. *Rev Mex Pediatr* 2008); 75: 175-180.

8. Sánchez-Castillo C P, Pichardo-Ontiveros E, et al. Epidemiología de la obesidad. *Gac Med Mex* 2004; 140: 2, s3-s20.

9. Fanjiang G, Kleinman R. Nutrition and performance in children. *Curr Opin Clin Nutr Metab Care* 2007; 10: 342-347.

10. Walker SP, Chang SM, Powell CA, et al. Effects of early childhood psychosocial stimulation and nutritional supplementation on cognition and education in growth-stunted Jamaican children: prospective cohort study. *Lancet* 2005; *366:* 1804-1807.

11. García EM, Padrón R J, Ortiz-Hernández L, et al. Efecto de la desnutrición sobre el desempeño académico de escolares. *Rev Mex Pediatr* 2005; 72: 117-125.

12. Navarro-Hernández Q, Navarro-Jiménez R. Evaluación de la relación entre el estado nutricio e índice de coeficiente intelectual en niños escolares. *Rev Fac Med UNAM* 2002; 45: 204-207.

13. Alaimo K, Olson CM, Frongillo EA. Food insufficiency and American school-aged Children's cognitive, academic, and psychosocial development. *Pediatrics* 2001; 108: 44-53.

14. Taras H, Potts-Datema W. Obesity and student performance at school. *J Sch Health* 2005; 75: 291–295.

15. Wang F, Veugelers PJ. Self-esteem and cognitive development in the era of the childhood obesity epidemic. *Obesity Review* 2008; 9: 615-623.

16. Gunstad J, Spitznagel MB, Paul RH et al. Cohen RA, Kohn M, Luyster FS, Clark R, Williams LM, Gordon E. Body mass index and neuropsychological function in healthy children and adolescents. *Appetite* 2008; 50*:* 246-251.

17. Richards M, Hardy R, Kuh D, et al. Birth weight, postnatal growth and cognitive function in a national UK birth cohort. *Int J Epidemiol* 2002; 31: 342-348.

18. Cserjési R, Molnár D, Luminet O, Lénárad L. Is there any relationship between obesity and metal flexibility in children? *Appetite* 2007; 49*:* 675-678.

19. Verdejo-García A, Pérez-Exposito M, Schmidt-Rio-Valle J, Fernandez-Serrano M, Cruz F, Pérez-García M *et al*. Selective Alterations Within Executive Functions in Adolescents With Excess Weigh. *Obesity 2010; doi:10.1038/oby.2009.475.*

20. Mond JM, Stich H, Hay PJ, et al. Associations between obesity and developmental functioning in pre-school children: a population-based study. Int J Obes (Lond) 2007; 31: 1068-1073.

21. Wachs T. Nutritional deficits and behavioral development. *Int J Behav Dev* 2000; 2: 435-441.

22. II Conteo de Población y Vivienda 2005. (2008). Proyecto IRIS-SCINCE II. [CD-ROM]. México: Instituto Nacional de Estadística y Geografía (INEGI).

23. Plan de desarrollo Urbano (PDU). (2010). Ciudad Juárez, México: Instituto Municipal de Investigación y Planeación (IMIP).

24. Aparicio RM, Estrada AL, Fernández C, Hernández RM, Ruiz M, Ramos D *et al.* Manual de Antropometría. 2nd ed. Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, CONACYT: México 2004.

25. Centers for Disease Control and Prevention (CDC). Percentile Data Files with LMS Values [document on the Internet]. CDC National Center for Health Stadistics [updated 2009 August 4; cited 2009 September 30]. Available from: http://www.cdc.gov/growthcharts/percentile_data_files.htm.

26. McLaren DS, Read WWC. Weigth/length classification of nutritional status. *Lancet* 1975,2, 219-221.

27. Waterlow JC. Classification and definition of protein calorie malnutrition. *BMJ* 1972; 3: 566-569.

28. Cattell RB, Cattell AKS. Factor “g” Escalas 2 y 3. 10 th. Tea Editions: Madrid, 2001.

29. Thurstone L.L, Thurstone ThG. Test de Aptitudes Escolares 1 (TEA.1) 11 th. Tea Editions: Madrid, 2004.

30. Kellogg CE, Morton NW. Beta III. Manual Moderno Editions: México, 2003.

31. Azurmendi, A, Braza, F, Sorozabal, A, et al. Cognitive abilities, androgen levels, and body mass index in 5-year-old children. *Hormones and Behavior,* 2005; 48: 187-195.

32. Caballero B. A nutrition paradox: Underweight and obesity in developing countries. *New England Journal of Medicine* 2005; 352(15): 1514-1517.

33. Foley J, Garcia J, Shaw L, et al. IQ predicts neuropsychological performance in children. *International Journal of Neuroscience* 2009;119 (10): 1830-1847.

Table1. Socio-demographic characteristics of the participants.

Socio-demographic Characteristic	MG	NNG	OG	F / Chi	*p*
Age of Mother (Mean / SD)	32.03(4.74)	32.51(5.94)	30.03 (2.44)	2.385	0.098
Mother's Educational Attainment % (n):				0.800	0.452
Elementary School	11.8 (4)	6.5 (2)	10.3 (3)		
Secondary School	24.4 (10)	33 (10)	37.9 (11)		
High School completed	47 (16)	38.8 (12)	34.5 (10)		
Technical degree	5.9 (2)	9.7 (3)	17.2 (5)		
Bachelors degree	5.9 (2)	12.9 (4)	0 (0)		
Mother's IQ(Mean/SD)	86.69(9.97)	86.12(8.28)	85.86(6.62)	0.079	0.924
Child's Gender (%)				3.384	0.038
Female	68.6	51.6	37.5		
Male	31.4	48.4	62.5		
Total	35.7	31.6	32.7		
Child's Age (Mean/SD)	8.54(0.50)	8.25(0.44)	8.37(0.49)	2.975	0.06
Social-economic status (%)					
Low	100	100	100		
Academic performance	7.9 (0.88)	8.2 (0.66)	8.6 (0.88)		

Scholar absenteeism	2.82 (3.44)	0.66 (0.83)	0.87 (1.45)
Physical activity performed (at least one hour per week) (%)	100	100	100

Nota: SD=Estándar Desviation

Table 2. ANOVA for IQ of three groups of children

Variable	MG M (SD)	NNG M (SD)	OG M (SD)	F	*p*	Post Hoc
Se	3.82 (2.66)	4.19 (1.86)	3.15 (2.60)	1.49	0.229	_
Cl	3.94 (1.92)	4.96 (2.15)	4.43 (2.22)	1.95	0.147	_
PM	4.45 (2.61)	4.61 (2.01)	1.96 (1.82)	5.5	0.005	(MG=NNG)>OG
TC	2.80 (1.49)	3.06 (1.93)	2.09 (1.27)	3.19	0.045	(MG=NNG)>OG
Tot DS	15.02 (6.89)	16.83 (5.79)	12.65 (4.45)	4.07	0.02	(MG=NNG)>OG

Note: M= Mean, SD= Standard Deviation, Se= Series, Cl= Classification, PM= Progressive Matrices, CT= Topological Conditions, Tot DP= Total Direct Score.

Table 3. ANOVA for three groups of academic performance

Variable	MG M (DT)	NNG M (DT)	OG M (DT)	F	ρ	Post Hoc
Dw	9.82 (1.27)	9.80 (1.13)	8.87 (1.86)	4.52	0.013	(MG=NNG)>OG
Dif Word	5.45 (2.54)	6.32 (1.73)	6.25 (2.85)	1.3	0.275	_
Voc	6.14 (2.92)	6.35 (2.24)	6.09 (2.38)	0.09	0.911	_
Ra	14.25 (4.38)	14.64 (5.43)	14.03(4.86)	0.12	0.881	
Cal	12.71 (6.18)	14.51 (5.03)	12.09 (4.92)	1.68	0.191	_
Tot G	47.94 (12.75)	51.64 (10.97)	47.34 (12.16)	1.18	0.31	_

Note: M= Mean, SD= Standard Deviation, Dw=Drawings, Dif. Word=Different Words, Voc=Vocabulary, Ra=Reasoning, Cal=Calculus.

Table 4. Relation between IQ and academic performance

	Total Direct Score		
Variable	MG	NNG	OG
DW	0.463**		0.472**
Voc		0.655**	0.585**
Ra	0.570**	0.645**	0.413*
Cal	0.603**		0.539**
Tot. Ver	0.360*	0.629**	0.673**
Tot. NV	0.571**	0.659**	0.510**
Tot G	0.662**	0.672**	0.650**

**=p<0.01; *= p<0.05

Anexo II

Malnutrition and Executive Functions in Spanish-speaking Children

Abstract

BACKGROUND:

The No Child Left Behind Act of 2001 and the Individuals with Disabilities Education Improvement Act of 2004 reemphasized the importance of innovative programs in schools to promote educational achievement and support cognitive development, and programs to promote adequate nutrition, based on scientific research.[1] Malnutrition has long been thought to affect learning. However, little empirical information exists to address the effect of malnutrition on neuropsychological functioning and academic performance, especially of Spanish-speaking children from a developing country.

METHODS:

To address this situation, a study was undertaken involving children and adolescents of low socioeconomic status, who were administered neuropsychological tests focusing on executive functions. The differences between groups (normal nutrition group vs. malnutrition group) and age (8 vs. 9 to 12 years) were analyzed using bifactorial MANOVA (two or more dependent variables in the neuropsychological test) or ANOVA (one dependent variable).

RESULTS:

The results indicate that neuropsychological domains were affected but that age was a factor in determining whether younger or older children were affected.

CONCLUSIONS:

This article provides evidence that could be the basis for integrating the tools of clinical neuropsychology into school-based psychological services.

Keywords: nutrition; malnutrition; executive functions; academic performance.

INTRODUCTION

Recently, the role of neuropsychology in the school has been emphasized due to the growing neuropsychological evidence of numerous learning and behavioral disorders, and to recent developments supporting neuropsychological testing in schools.[2] A number of medical influences, including neurological conditions (i.e., infants with low birth weight, children with head injuries), mental health problems (i.e., behavioral and social-emotional problems, attention deficit disorder and hyperactivity disorder), and altered nutritional conditions (i.e., malnutrition, obesity), are driving the interest in school neuropsychology.[2]

Malnutrition is also an important issue in education, because it affects cognitive development and academic performance. Researchers have exhaustively reviewed published studies about nutrition among school-age children and have shown that school feeding can help improve academic performance and cognitive functioning among children, particularly malnourished children.[3-5]

However, most of the cognition and malnutrition studies focus on pregnancy and infancy.[6,7] Few studies have focused on the later ages of children.[8] Although most of these studies are not recent, it has been found that stunting (as a measure of malnutrition) at an early age negatively affects non-verbal intelligence at later ages.[9] Likewise, a study has shown that children who were severely malnourished during their first year of age had lower scores on the WAIS test, on Raven´s Progressive Matrices, and in academic performance at the end of high school.[10]

In particular, an important brain function that has been found to be affected in malnourished children is executive function (EF),[11] although it is difficult to measure at early ages,[12] because it develops with age. In a recent study undertaken in India, children between the ages of 5 and 10 with protein-energy stunting (as a measure of malnutrition) showed a lower performance in EF compared with normally nourished children.[11] Specifically, the study found that malnourished children had poorer performance in working memory tests, particularly in phonetic fluency, than did normally nourished children. There is no more research linking EF with malnourished children.

In the above-mentioned study, the authors found differences in EF depending on the age of the children; the age group consisting of children from 8 to 10 years old had better performance in phonetic fluency tests compared with the group of children from 5 to 7 years of age. In the same test, however, children from 8 to 9 years old showed no significant differences from the children of 10 to 11 years of age.[12] Some researchers agree that children from 8 to 11 years old obtain scores from 11 to 15 words in semantic fluency and from 6 to 8 words in phonetic fluency, and children do not reach adult maturity levels until the age of 12 years.[12] Another recent study found that 8-year-old children made more mistakes due to lack of attention, impulsivity, and distractions compared with 10 to 12 year-old children.[13] This study did not consider the academic performance of participants. Only a few studies have examined the relationship between malnutrition and academic achievement in older children, and have found associations between malnutrition and lower academic performance.[14] In this type of studies, however, neurocognitive measures such as executive function have not been considered.

There are few studies on cognitive performance in malnourished children of 8 to 12 years of age, especially when measuring EF and academic performance. Indeed, most studies on EF have been based on attention deficit disorder and hyperactivity disorder, autism, schizophrenia, depression, or traumatic brain injury.[15-16] However, the evidence points to the likelihood that malnutrition is associated with impaired cognitive abilities in later life.

The aim of this study was to investigate how malnutrition affects EF and academic achievement in children of 8 to 12 years of age. We hypothesized that malnourished children have impaired executive skills and will have worse performance on executive tasks and academic performance compared with normally nourished children.

METHODS

Subjects

The study was conducted in two schools in Ciudad Juarez, located in Chihuahua State, Mexico. A total of 78 children in the age group of 8 to 12 years (32 boys and 46 girls; *M*= 9.18, SD= 1.046) participated in the study. The students were enrolled in the third, fourth, fifth, and sixth grades. Out of the sample, 52 children were malnourished (MG) and 26 were with normal nutrition (NNG). The socioeconomic status (SES) of subjects in the sample was low, living in an urban area. Exclusion criteria included any pre-existing neurological disease (e.g., brain injuries, epilepsy, and degenerative syndromes) and hormonal diseases (e.g., diabetes or thyroid-related diseases). Table 1 shows the socio-demographic and clinical characteristics.

The children's parents were informed about the study and, if they allowed their children to participate, their consent was obtained. The study was also approved by the Bioethics Committee of the Autonomous University of Ciudad Juarez (UACJ).

Materials

Anthropometric Measurements. The anthropometric measurements were identified as core measures (weight and height) and anthropometric indices (McLaren index, percentages of weight/age, height/age, and weight/height). The anthropometric measurements were performed according to the specifications of the anthropometry manual of the National Council for Science and Technology (CONACYT).[20] Weight was determined by a Seca® electronic scale. Size was measured with the subject in a standing position, with the head placed so that the plan of Frankfurt was at the horizontal position; a Harpenden stadimeter was used to get these measurements. All subjects wore light clothing (i.e., blouse, skirts, and undergarments for girls; shirt, trousers, and undergarments for boys) and no shoes during the anthropometric data collection phase. The reference standards for weight and height were the curves and growth tables taken from the National Center for Health Statistics (NCHS) in collaboration with the National Centers for Chronic Disease Prevention and Health Promotion in 2000.[21]

Executive Function Measures. EF measures were obtained using several different measures. EF was divided into three basic components: updating, inhibition, and shifting.[22, 23]

1. - Inhibition Measurements:

- The Spanish children's version of the Stroop Color and Word Test.[24] The test contains three lists. Children have to read words in the first list, say the name of colors in the second list, and say the name and color of the printed words as quickly and as accurately as possible in 45 seconds per task in third list.

- The go/no-go task.[25] The task consists of 100 trials (50 go and 50 no-go). The individual is asked to press a computer key as quickly as possible if a go stimulus appears and not to press the key if the no-go stimulus shows (this part was a preswitch). During the next part of the test (postswitch) when a sound is heard, the task is inverted: the go stimulus is now the no-go stimulus, and vice versa. The go and no-go stimuli are represented by a dolphin and a bear, respectively. Every time the subject gives an answer a sound feedback (one of two) is given telling the subject if the answer was correct or incorrect. The inter-stimulus interval (ISI) was set at 100 ms, and each stimulus was presented for 1000 ms. The main dependent variables from this test were hit and false-alarm rates. These variables were analyzed across 10 blocks of 10 trials to explore the effects of learning and switching during the task.

2. Updating Measurements:

- Letter-number sequencing. This subtest of the WISC-IV[26] (Spanish Version) consists of giving the subject a mixed set of numbers and letters orally, with the subject having to complete two tasks. First, the subject has to arrange the numbers in ascending order orally and then arrange the letters in alphabetical order orally from the previously given set.
- Matrix reasoning.[29] The goal is to complete the picture matrix with any of the given solutions.
- Phonetic verbal fluency.[27] Subjects are asked to say all the words they can recall beginning with the sound “m” in a one-minute period. The task excludes proper

nouns, repeated words, or derived words in Spanish, such as “muñeca” and “muñequita”.

- Semantic fluency (fruit and animals).[27] Subjects are asked to say all the names of animals or fruits that they can remember in a one-minute period. The task excludes repeated words, or referrals as “pollo” and “pollito”.

3.- Shifting measures:

- Trail-making test.[28] This test has two parts, A and B. The participant in part A must join with lines the numbered circles in a consecutive form. In part B, the participant must join the circles with numbers and letters consecutively.

4. Academic performance. Academic performance was the average of the ratings that the children had in the subjects of Spanish, Mathematics, History, Geography, and Science.

5. Absenteeism. Absenteeism consisted of the times the child did not go to school in the two months before the study was conducted.

Procedure

Students were recruited from two schools in the low socioeconomic area of Ciudad Juarez, Mexico. SES was based on the II Conteo de Poblacion y Vivienda, 2005[17] data covering such areas as illiteracy, number of individuals living per room, etc., which are the foundation of an SES system. SES was classified as follows: 1, very low SES; 2, low SES; 3, middle SES; 4, high SES; 5, very high SES. According to the Plan de Desarrollo Urbano[18] of Ciudad Juarez, the residents of the two neighborhoods used for the study are of the low-SES group. A public meeting was held and parents were informed about the project. An informed consent form was provided to the parents who showed interest in participating in the study.

The mothers then completed the Beta III[19] to assess their IQ. In addition, a demographic questionnaire was administered to the parents to obtain data about the children's development and disease history. During the following days anthropometric measurements were taken to determine the nutritional status of the participating children. Malnourished children were defined as those who had less than 90% of the expected weight conforming to age and height, considering the percentile 50 value of the NHCS standards as the expected weight. Tests were then administered individually to the children in an isolated room during school hours by a trained technician.

Data analysis

The independent variable was nutritional status (NS), which was divided into two groups: normal nutrition (NNG) and malnourished (MG). The ages of the children were divided into two groups: 8 years and 9 to 12 years. The dependent variables were the scores obtained on each EF test, and each of academic performance scores:

- Letter and number sequence (L&N): direct score in the letter and number sequence test;
- Matrix reasoning (MR): direct score in the matrix test;
- Stroop Word (SW): direct score in Stroop Word;
- Stroop Color (SC): direct score in Stroop Color;
- Stroop Color-Word (SCW): direct score in Stroop Color-Word;
- Go/No-go hits (Go-H): rate of hit;
- Go/No-go hits (Go-FA): rate of false-alarm;
- Trail-making test (TMT): direct score in the trail-making test;
- Absenteeism: total absenteeism in the bimester;

- Academic performance: the average of the ratings that the children had in the subjects of Spanish, Mathematics, History, Geography, and Science.

To analyze the differences in socio-demographic variables, ANOVA Chi-Square across tables was conducted according to the variables. The differences between groups (NNG vs. MG) and age (8 vs. 9 years old) were analyzed using bifactorial MANOVA (two or more dependent variables in the neuropsychological test) or ANOVA (one dependent variable).

RESULTS

First, ANOVA and Chi-square analysis of socio-demographic differences revealed no significant differences in any of the variables between NNG and MG (see Table 1).

Executive function differences between the groups

In the updating component, the results of MANOVA showed significant differences among age groups in L&N, F (1,74) = 7.49, $p<0.008$, and in MR, F (1,74) = 0.410, $p<0.046$, with children older than 9 years of age showing better performance compared with children 8 years of age. Significant differences were found in the fluency task for all three conditions, Lambda (1, 74) = 0.249, $p<0.000$ and such differences depended on age, Lambda (1, 74) = 0.838, $p<0.002$. Moreover, children 8 years of age showed worse performance than children 9-12 years of age in the animals condition, F = 20.599, $p<0.000$ (see Table 2).

In the inhibition component, however, when the NS and the age group variables were considered, significant differences were found for the go/no-go task, in Go-FA conditions [Lamda (9,64) = 0.743; $p<0.018$] and Go-H [F (Sphericity assumed) (1,72) = 2.065; $p<0.031$] reflected in the 9-12 year-old MG, which showed lower performance compared with the 9-

year-old NNG. Go-FA and Go-H rates were then computed for each of the 10 phases (see Table 3). There were no significant phases in Go-FA at 8 years, but blocks 3 (F= 13. 112, *p*<.001,) 8 (F= 5.111, *p*<.029), and 9 (F = 8.296, *p*<.006) at 9 years were significant. In Go-H at 8 years, blocks 1 (F = 14. 767, *p*<.001), 8 (F = 12.123, *p*<.002), and 9 (F =10.154, *p*<.003) were significant; at 9 years, blocks 3 (F= 7.574, *p*<.008), 6 (F = 7.335, *p*<.010), and 10 (F= 19.810, *p*<.000) were significant, with malnourished 9-12year-old children having worse performance for both rates compared with the 9 years and older NNG.

In the Stroop test, all three conditions showed differences between age groups [Lambda (3.72) = 0.796; p<0.001]. The subsequent univariate results showed that the two age groups were significantly different for the conditions SW [F (1, 74) =7.831; *p*<0.007], SC [F (1, 74) = 18.23; *p*< 0.000] and SCW [F (1, 74) =7.090; *p*<0.010], reflecting the lower performance of the younger age group (see Table 2).

Finally, similar results were found for the flexibility component. In TMT the two conditions of MANOVA showed significant differences between the age groups [Lambda (1, 65) = 0.653; *p*<0.000]. These differences depended on age [Lambda (1,65)= 0.906; *p*<0.012], with the performance of 8-year-old children being below that of children 9 years of age or older in both conditions TMT-A (F = 28.195; *p*<0.000) and TMT-B (F = 12.192; *p*<0.001) (see Table 2).

Academic performance, absenteeism nutritional condition, and executive functioning

We examined whether the MG and NNG differed in academic performance and absenteeism. The results showed that malnourished children had significantly lower academic achievement (NNG=8 vs. MG=7) [t(1,76)= -2.649; p< 0.010] but the same statistical absenteeism (NNG=1.3 vs. MG=2.09).

To explore if neuropsychological performance was related to academic performance and nutritional status, Pearson correlations were conducted between academic achievement and the EF variables separately for each group. The results showed that abstract reasoning, working memory, and resistance to interference in the Stroop among malnourished children were positively related to better grades. In the group of healthy children no relationship was obtained (see Table 3).

On the other hand, in the case of absenteeism, verbal fluency (fruits) and working memory were inversely related in MG, and the measures of processing speed (Stroop color and time of TMT-A) in NNG (see Table 3).

DISCUSSION

The main objective of this research was to study malnutrition and EF in Spanish-speaking children. The results indicate that the MG showed worse execution in the impulsivity task (go/no-go), but this depended on the age of the children (only in the 9-12 years age group). Our results also showed that executive functions are related to academic performance and absenteeism in the malnourished group but not among healthy children.

It is important to point out that the EF abilities can be measured starting at the age of 7.[29,30] The lack of significance at the age of 8 may be due to incomplete frontal maturation instead of other factors such as malnutrition. Further, performance on EF measures does improve with development.[31-33] The results show that at the age of 9 years, the MG does not reach the development level of the NNG. One of the aspects measured by the go/no-go task is motor impulsivity, which is a reliable indicator of impulsive behavior.[34] Hence, a salient explanation may be impulsivity or, alternatively, disinhibition.

In contrast, in the age variable, the present results support the findings of Williams et al.,[33] who also found that in the Stroop signal task (an inhibition task like go/no-go) 9- to 12-year-old children responded better than did 8-year-olds. In the Stroop test our results showed that 8-year-old children have lower performance than children 9 years of age and older. Children less than 8 years of age do not appear able to answer correctly.[33] They improve their performance at 9 years of age, reaching the maximum performance when they reach adolescence or at later ages.[35] In fluency, the results showed significant differences by age group, with the group of 9-year-olds showing improved performance in the animals category. An explanation for this is that animals are a natural category, which is one of the first types of narrative categories to be mastered. Scores on animal fluency continue improving until the age of 12 years, whereas scores on fruits continue to increase until the age of 12 to 15 years.[36] Further, the present results are consistent with Brocki and Bohlin[37] and with Kar et al.,[11] who found that developmental differences depend on the EF component measured. In general we agree with Kalkut, Han, Lassing, Holdnack, and Delis,[38] in the sense that the performance of EF tasks improves with age.

Our results also show a relation between academic performance, absenteeism, and EF measures in the malnourished group but not in the healthy one. These results are consistent with a previous paper that found low cognitive and academic performance in malnourished children. However, we found a differential relationship for academic achievement and absenteeism: the former is related to updating and inhibition measures and the latter to flexibility. This enhances the importance of measuring EF in malnourished children.

Limitation

It is important to highlight that the present sample was socioeconomically homogenous. In addition, severely malnourished children were not included in the study and could play a significant role in helping to explain a more complex picture of the relationship between malnutrition and neuropsychological functioning.

Implications for schools

These results do point to a strong association between malnutrition, executive dysfunction, and academic performance. It is necessary to emphasize the importance of adequate nutrition for students, because the bad consequences of malnutrition can be observed from school age. Preventing malnutrition in school in underdeveloped countries is essential for good academic performance by children and later by adults. Toward this end it is necessary to create programs that teach proper nutrition in childhood.

References

1. US Department of Education. The Elementary and Secondary Education Act: PL 107-110, the No Child Left Behind Act of 2001. Available at: http://www.ed.gov/policy/elsec/leg/esea02/index.html. Accessed June 16, 2011.

2. Clearly MJ, Scott AJ. Developments in clinical neuropsychology: implications for school psychological services. *J Sch Health.* 2011; 81: 1-7.

3. Hoyland A, Dye L, Lawton CL. A systematic review of the effect of breakfast on the cognitive performance of children and adolescent. *Nutr Res Rev.* 2009; 22:220-243.

4. Grantham-McGregor S. Can the provision of breakfast benefit school performance? *Food Nutr Bull.* 2005; 26 (2): s144-158.

5. Taras H. Nutrition and student performance al school. *J Sch Health.* 2005; 75 (6): 199-213.

6. Fanjiang G, Kleinman R. Nutrition and performance in children. *Curr Opin Clin Nutr Metab Care.* 2007; 10: 342-347.

7. Walker SP, Chang S, Powell CA, Grantham-McGregor S. Effects of early childhood psychosocial stimulation and nutritional supplementation on cognition and education

in growth-stunted Jamaican children: prospective cohort study. *Lancet*. 2005; 366: 1804-1807.

8. Benton D. The influence of children´s diet on their cognition and behavior. *Eu J Nutr*. 2008; 47(3): 25-37.

9. Mendez M A, Adair LS. Severity and timing of stunting in the first two years of life affect performance on cognitive test in late childhood. *J Nutr.*1999; 129: 1555-1562.

10. Ivanovic R, Forno H, Durán MC, Hazbún J, Castro C, Ivanovic D. Estudio de la capacidad intelectual (Test de Matrices Progresivas de Raven) en escolares de 5 a 18 años. Antecedentes generales, normas y recomendaciones. *Revista de Psicología General y Aplicada*. 2000; 53: 5-30.

11. Kar BR, Rao SL, Chandramouli BA. Cognitive development in children with chronic protein energy malnutrition. *Behav Brain Funct.* 2008; 4(31): doi: 10.1186/1744-9081-4-31.

12. Koren R, Kofman O, Berger A. Analysis of word clustering in verbal fluency of school-aged children. *Arch Clin Neuropsych.* 2005; 20: 1087-1104.

13. Klimkeit EL, Mattingley JB, Sheppard DM, Farrow M, Bradshaw JL. Examining the development of attention and executive functions in children with a novel paradigm. *Child Neuropsychology.* 2004; 10: 201-211.

14. Themane MJ, Monyeki KD, Nthangeni HC, Kemper G, Twisk JWR. The relationship between health (malnutrition) and educational achievements (Maths and English) in the rural children of South Africa. *Int J Educ Dev.* 2003;23:637-643.

15. Dennis M, Agostino A, Roncadin C, Levin H. Theory of mind depends on domain-general executive functions of working memory and cognitive inhibition in children with traumatic brain injury. *J Clin Exp Neuropsychol.* 2009; 32(7): 835-847.

16. Nyberg L, Brocki K, Tillman C, Bohlin G. The proposed interaction between working memory and inhibition. *Eur J Cognit Psychol.* 2009; 21(1): 84-111.

17. II Conteo de Población y Vivienda 2005. Proyecto IRIS-SCINCE II. [CD-ROM]. Instituto Nacional de Estadística y Geografía (INEGI); 2008.

18. Plan de desarrollo Urbano (PDU) 2010. Ciudad Juárez, México: Instituto Municipal de Investigación y Planeación (IMIP); 2010.

19. Kellogg CE, Morton NW. *Beta III*. Manual Moderno Editions: México; 2003.

20. Aparicio RM, Estrada AL, Fernández C, et al. *Manual de Antropometría*. 2nd ed. Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, CONACYT: México; 2004.

21. National Center for Health Statistical in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000). Available from: Http://www.cdc.gov/grownthcharts

22. Fisk JE, Sharp CA. Age-related impairment in Executive Functioning: Updating, inhibition, shifting and access. *J Clin Exp Neuropsychol.* 2004; 26: 874-890.

23. Verdejo-García A, Pérez-García M. Profiles of executive deficits in cocaine and heroin polysubstance user: common and differential effects on separate executive components. *Psychopharmacology.* 2007; 190: 517-530.

24. Golden CJ. *Stoop Test de Colores y Palabras*. 4th. Madrid: Tea Editions; 2005.

25. Perales, 2003 cited by Verdejo-García A, Bechara A, Recknor E C, Pérez-García M. Frontal behavioral deficits in substance dependent individuals during drugs use and during abstinence: An examination of the behavioral, cognitive and emotional correlates of addiction. *JINS.* 2006; 12: 405-415.

26. Wechsler D. *Escala de inteligencia de Wechsler para Niños-IV (WISC-IV).* México: Manual Moderno; 2007.

27. Matute E, Rosselli M, Ardila A, Ostrosky-Solís F. *Evaluación Neuropsicológica Infantil (ENI).* México: Manual Moderno; 2007.

28. Reitan RM. Validity of the Trail Making Test as an indicator of organic brain damage. *PerceptMot Skills* 1958; 8: 271-276.

29. Schachar R, Logan GD. Impulsivity and inhibitory control in normal developmental. *Develop Psychol.* 1990; 26(5): 710-720.

30. Best JR, Miller PH, Jones LL. Executive functions after age 5: Changes and correlates. *Developmental Review.* 2009; 29: 180-200.

31. Huizinga M, Dolan C, van der Molen M. Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologi.* 2006; *44*: 2017–2036.

32. Nigg JT, Quamma JP, Greenberg MT, Kusche CA. A two-year longitudinal study of neuropsychological and cognitive performance in relation to behavioural problems and competencies in elementary school children. *J Abnorm Psychol.*1999; 27(1): 51-63.

33. Williams BR, Ponesse JS, Schachar RJ, Logan GD, Tannock R. Developmental of inhibitory control across the life span. *Develop Psychol.*1999; 35(1): 205-213.

34. Dougherty DM, Bjork JM, Harper RA, et al. Behavioral impulsivity paradigms: a comparison in hospitalized adolescents with disruptive behavior disorder. *J Child Psychol Psychiatry.* 2003; 44: 1145-1157.

35. Crone EA. Executive functions in adolescence: interferences from brain and behavior. *Dev Sci*. 2009; 12(6): 825-830.

36. Valencia NJ, Laserna JA, Pérez-García, M, et al. Influencia de la escolaridad y el sexo sobre la ejecución en el FAS, nombrar animales y nombrar frutas. *Pscol Conduct*. 2000; 8(2): 283-295.

37. Brocki KC, Bohlin G. Executive functions in children aged 6–13: A dimensional and developmental study. *Dev Neuropsychol.* 2004; 26: 571–593.

38. Kalkut EL, Han SD, Lansing AE, Holdnack JA, Delis DC. Development of Set-Shifting ability from late childhood through early adulthood. *Arch Clin Neuropsych*. 2009; 24: 565-574.

Table 1 Sociodemographics Characteristics of the participants		
	MG	***NNG***
Age of Mother (Mean / SD)	32.42 (4.55)	33.92 (5.83)
Mother's Education (%):		
Elementary school	7.7	7.7
Elementary school not completed	0	3.8
Secondary	28.8	23.1
Secondary not completed	3.8	11.5
High School	34.6	19.2
High School not completed	3.8	3.8
Technical degree	11.5	19.2
Bachelors degree	3.8	11.5
Mother's IQ (Mean/SD)	85.33 (9.47)	84.19 (10.96)
Child Gender:		
Female	59.6	57.7
Male	40.4	42.3
Total	59	41
Child age (Mean/SD	9.25 (1.10)	9.05 (0.92)
Social-economic status (%)		
Medium - Low	*100*	*100*
Academic performance	7.91 (0.90)	8.5 (0.87)
Scholar absenteeism	2.09 (2.70)	1.23 (2.08)
Physical activity performed (at least one hour per week) (%)	100	100

Table 2. MANOVAS and ANOVAS of the function executive measuerements

Domine	Variable	MG(M and SD)		NNG (M and SD)		Main effects / Interactions	F/ Lambda	Significance	Univariate Contrasts	
		8 years	*9 to 12 years*	*8 years*	*9 to 12 years*				*F*	*ρ*
Updating	**L&N**	8.59 (5.04)	10.50 (5.05)	6.90 (5.43)	12.20 (6.51)	Age	7.49	0.008	N/A	N/A
	Animals	7.68 (2.91)	11.43 (2.88)	9.00 (2.64)	10.93 (3.69)	Fluency			20.559	0
	Fruit	7.77 (1.57)	8.56 (2.23)	8.72 (2.00)	8.06 (2.34)	Fluency*Age	0.249	0.000	0.427	0.515
	"m" Sound	4.40 (2.08)	5.56 (2.76)	3.63 (1.85)	4.40 (2.89)		0.838	0.002	3.156	0.08
	MR	11.68 (3.53)	12.46 (4.04)	12.00 (3.54)	15.00 (4.03)	Age	4.1	0.046	N/A	N/A
Inhibition	**SW**	55.40 (12.03)	60.86 (16.51)	47.09 (16.99)	61.66 (12.53)				0.007	7.831
	SC	38.68 (7.10)	48.06 (10.09)	37.36 (4.58)	44.73 (6.49)				0	18.233
	SCW	20.72 (4.14)	24.30 (5.51)	21.36 (4.20)	24.86 (7.52)	Stroop	0.796	0.001	0.01	7.09
	Go-FA*					Go-no-go*	0.743	0.018		
	Go-H*					age*Group	2.065	0.031		
Shifiting	**TMT A**	08.90 (74.33	25.34 (36.19)	96.75 (19.27)	67.17 (44.71)	TMT	0.653	0	28.195	0
	TMT B	68.86 (135.8(	43.94 (76.42)	14.64 (151.0	51.72 (98.42	TMT*Group	0.906	0.012	12.192	0.001

Note: * Results on the go-no go by blocks are shown; M= Mean; SD= Standard Deviation; L&N= Letter and Number Sequence; MR= Matrix Reasoning; S.W= Stroop Word; S.C:= Stroop Colors; S.C.W =Stroop Color-Word; GO-FA= Go/no-Go False alarm; Go-H=Go/no-Go Hits; N/A = Not applicable.

Table 3. Pearson correlation between academic performance, absenteeism and executive functions.

Domain	Variables	*MG*		*NNG*	
		Academic performance	Absenteeism	Academic performance	Absenteeism
Updating	L&N	0.273*	-0.301*		
	Animals				
	Fruit		-0.449**		
	"m" sound				
	MR	0.368*			
Inhibition	SW				
	SC				-.0470*
	SCW	0.303*			
	Go-FA				
	Go-H				
Shifting	TMT-A				0.436*
	TMT-B				

Note: **=p<0.01; *= p<0.05. L&N= Letter and Number Series; MR= Matrix Reasoning; SW= Stroop Word; SC= Stroop Colors; SCW= Stroop Color-Word; Go-FA= Go/no-Go False alarm; Go-H= Go/no-Go Hits; TMT A= Trail Making Test A; Trail Making Test B.

Anexo III

Titulo: Psicopatologías en niños desnutridos medidas con el CBCL/6-18.

Title: Psychopathology in malnourished children measured with the CBCL/6-18.

Titulo breve: Estados nutricios y psicopatologías en niños.

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Resumen

Objetivo. Estudiar la presencia de trastornos psicopatológicos asociados a la desnutrición en niños, así como establecer el grupo de referencia normativo al cual pertenece México en la escala Child Behavioral Check List 6-18 (CBCL/6-18). Material y métodos: Se utilizó la información de 85 niños en estados de desnutrición y normopeso, obtenida mediante el CBCL 6-18, para establecer primeramente, el grupo normativo de referencia multicultural al cual pertenece México y posteriormente, estudiar las posibles diferencias entre los grupos. Resultados: México, pertenece al grupo normativo de referencia tres; encontramos que los niños presentan problemas tanto internalizantes como externalizantes.

Palabras Clave: Desnutrición, Estados nutricios, Psicopatologías en niños

Abstract

Objective. To study the presence of psychopathological disorders associated with obesity and malnutrition in children, and establish the normative group to which Mexico belongs in the Child Behavioral Check List 6-18(CBCL/6-18). Material and methods: It used the information of CBCL/6-18 from 85 children in malnourished and normal nutrition states to establish at first, with T scores, is the multicultural normative group to which Mexico belongs and then, analyze with ANOVAS the possible differences between each nutritional group according to the instrument's scales. Results: Mexico belongs to the normative group three. We found that the malnourished children present internalizing and externalizing problems.

Key Words: Malnourished, Nutritional status, Children psychopathology

INTRODUCCION

La desnutrición es un problema alimenticio que afecta a la salud pública, particularmente, a los países en vías de desarrollo especialmente durante la niñez. Datos del 2008 proporcionados por la UNICEF[1], afirman que México ocupa el lugar 22 de entre los primeros 24 países con el mayor número de niños menores de 5 años con desnutrición y el único de ellos, que no se encuentra en África o en Asia.

Las cifras son alarmantes debido a las repercusiones que tiene este problema. Por ejemplo, la desnutrición contribuye a aumentar los gastos en la atención de la salud pública[2]. A nivel individual, disminuye la productividad[2] y el rendimiento físico y cognitivo[3]. Además, los niños desnutridos tienen más riesgo de padecer enfermedades infecciosas (como malaria, diarrea, sarampión y neumonía)[4].

Por otro lado, el desarrollo de trastornos psicopatológicos durante la niñez ha sido estudiado por diversos autores. Sin embargo existen escasos estudios sobre la asociación entre estos y la desnutrición[5]. Además la relación adversa que guardan con este estado nutricio es poco definida[6]. En uno de los trabajos que trata sobre la dieta y psicopatologías en adolescentes, se evidencia la asociación entre una salud mental más pobre y la dieta occidental (la cual se caracteriza por un mayor consumo de carne roja y azúcares[5]). Además asocian a los problemas externalizadores, con una dieta de baja calidad[6].

En cuanto a investigaciones recientes, con niños desnutridos y su relación con psicopatologías, se encuentra que la desnutrición durante la infancia se asocia a problemas externalizadores en la niñez[6].

De nuestro conocimiento, no existen trabajos que hayan realizado una exploración amplia de la salud mental de niños desnutridos. Estos sólo se pueden realizar con instrumentos amplios que midan las principales alteraciones psicopatológicas en los niños. En este sentido, el instrumento más utilizado es el Child Behavioral Check List (CBCL 6/18) desarrollada por Thomas M. Achenbach y Craig Edelbrook, que mide de modo fiable los principales síntomas psicopatológicos. No obstante, existen escasos trabajos que hayan utilizado el CBCL 6/18 en niños mexicanos[7-9] y, menos aún, en niños desnutridos.

Además, no existe ningún estudio en niños mexicanos que haya utilizado la última versión del CBCL/6-18 que incorpora nuevas medidas psicopatológicas y especialmente, baremos agrupados por culturas para aquellas sociedades en las que no se ha normalizado este instrumento[10].

Por ello, el objetivo del presente trabajo ha sido estudiar la presencia de trastornos psicopatológicos asociados a la desnutrición en niños. Hipotetizamos que los niños desnutridos presentarán problemas psicopatológicos comparados con niños de su misma edad y su mismo entorno sociocultural. Además, como objetivo secundario, se estudiará cual es el grupo normativo de referencia multicultural del CBCL/6-18[11] para los niños mexicanos.

MATERIAL Y MÉTODOS

Participantes

Este estudio fue realizado en dos escuelas de Ciudad Juárez, México, se reclutaron 85 niños (39 niños y 46 niñas), de entre 8 y 12 años de edad, que cursaban de tercero a sexto de educación primaria. De la muestra de estudio, 44 niños presentaron desnutrición leve a moderada, y 41 peso normal. Todos los sujetos provenían de status socioeconómico bajo, de entornos urbanos. Como criterios de exclusión se tomaron la presencia de enfermedades neurológicas (parálisis cerebral, epilepsia, lesiones cerebrales, síndromes neurológicos detectados) y enfermedades hormonales (diabetes o enfermedades relacionadas con la tiroides). Previamente se les pidió por escrito a los padres de los niños que firmaran un consentimiento informado. Cabe mencionar que este proyecto, incluyendo el consentimiento informado, fue autorizado por el comité de bioética de la Universidad Autónoma de Ciudad Juárez. Las características demográficas y clínicas de la muestra se pueden ver en la Tabla 1.

Medidas Antropométricas

Para la evaluación antropométrica se determinaron medidas básicas (peso y talla) e índices antropométricos (Índice de McLaren, Porcentajes del peso/edad, talla/edad y peso/talla). Las mediciones antropométricas se realizaron según las especificaciones del manual de antropometría del Consejo Nacional de Ciencia y Tecnología (CONACYT)[12]. El peso se determinó mediante báscula electrónica marca Seca. La talla se midió en posición de pie, con la cabeza colocada de tal forma que el plano de Frankfurt se situaba en posición horizontal, se utilizó estadímetro marca Harpenden. Los estándares de referencia para peso y talla fueron las curvas y tablas de crecimiento de los Centros para el control y prevención de enfermedades(CDC) del 2000[13]. Para el diagnóstico del estado nutricio se utilizaron las clasificaciones de McLaren y Read[14] y Waterlow[15].Considerando como desnutridos a los participantes que presentaron menos del 90% del peso esperado para la edad y la talla.

Medidas Psicopatológicas.

Se utilizó la traducción y adaptación mexicana[8] de la versión más reciente del Child Behavioral Check List (CBCL/6-18)[10], la cual mide psicopatologías en niños y adolescentes y consta de 113 reactivos, divididos en 8 factores o escalas sindrómicas empíricas, las cuales son: depresión-ansiedad, aislamiento, quejas somáticas, problemas sociales, problemas de pensamientos, problemas de atención, quebrante de normas y conducta agresiva. Las puntuaciones de estos factores se agrupan en dos escalas: problemas internalizadores y problemas externalizadores y estas a su vez en una escala llamada total de problemas. Actualmente cuenta con 6 subescalas orientadas al DSM (trastornos afectivos, quejas somáticas, déficit de atención/hiperactividad, trastorno oposicionista y trastorno de conducta). Con la versión de 2007, se añadieron el trastorno obsesivo compulsivo y el trastorno por estrés post-traumático. Para el sistema de corrección se utilizó el sistema informatizado ADM desarrollado por Achenbach.[11]

Procedimiento

Se les pidió a dos escuelas de una zona socioeconómica baja la participación en el proyecto. Se realizó una reunión y se solicitó a los padres el consentimiento informado, mediante un documento en dónde se explicaba el procedimiento que se llevaría a cabo. En los días posteriores se tomaron medidas antropométricas para clasificarlos por estado nutricio.

Una vez obtenida la clasificación de la muestra, se les aplicó el CBCL/8-16 a las madres o a los tutores de los niños.

Variables y análisis estadísticos

La variable de agrupación o independiente fue el estado nutricio dividido en dos grupos: normopeso (GNP), desnutridos (GD).

Como variables dependientes se utilizaron cada uno de los ocho factores y de las dos escalas del CBCL/ 6-18 proporcionadas por el sistema de corrección ADM y el total de problemas. Además de cada una de las escalas orientadas al DSM:

Ansiedad/Depresión (Ans/Dep).

Aislamiento (Ais).

Queja Somática (QS).

Problemas Sociales (PS).

Problemas Pensamiento (PP).

Problemas de Atención (PA).

Quebranto de normas (QN).

Agresividad (Agr).

Internalizadores (Int).

Externalizadores (Ext).

Total de Problemas (Tot P).

Trastorno afectivo (T Afe).

Trastorno de Ansiedad (T Ans).

Problemas Somáticos (P Som).

Trastorno por Déficit de Atención con Hiperactividad (TDAH).

Trastorno Oposicionista (T Opo).

Trastorno de Conducta (P Cond).

Trastorno Obsesivo compulsivo (TOC).

Trastorno por estrés postraumático (TEPT).

Para los análisis estadísticos, en primer lugar se obtuvieron las puntuaciones T de nuestra muestra aplicando los baremos del Grupo 1, 2 o 3 del software ADM[11]. Se seleccionó como grupo de referencia normativa aquel que proporcionara puntuaciones T más próximas a 50 en la mayoría de los factores y escalas.

Posteriormente, se procedió a estudiar las posibles diferencias entre los grupos en las puntuaciones T de los factores y escalas del CBCL incluyendo las escalas DSM. Para esto, se realizó un análisis *t* de Student utilizando la variable grupo diagnóstico como factor (GD vs. GNP), las puntuaciones en los factores, las escalas y la puntuación total de problemas y las escalas orientadas al DSM, como variables dependientes.

Debido al número de análisis realizados y al carácter exploratorio de esta investigación el nivel de esta significación estadística se fijó al 0.01.

Por último, aplicando los puntos de corte establecidos por Achenbach y Rescorla[10] se obtuvo el porcentaje de niños que estaban en el límite o dentro del rango de deterioro clínico.

RESULTADOS

1. *Buscar el grupo de referencia normativo de los baremos multiculturales de Achenbach y Rescorla*[10].

Se procedió a determinar cual grupo de referencia normativo de estudios internacionales del CBCL (Grupo 1 vs. Grupo 2 vs. Grupo 3) se ajustaba mejor a los niños mexicanos. Como se puede ver en las figuras 1 y 2, el grupo de referencia 3 fue en donde la muestra de niños mexicanos se acercaba más a la medida de 50 en puntuaciones T, en la mayoría de los factores y escalas.

Una vez establecido el grupo de referencia, se obtuvieron las puntuaciones T tanto para el grupo de niños obesos y desnutridos utilizando el grupo de referencia normativo 3 (GN3) y con estas puntuaciones se hizo el resto de comparaciones.

2. Diferencias entre los niños desnutridos y normopeso en las escalas de síndromes empíricos y las orientadas al DSM

Los resultados mostraron que existían diferencias estadísticamente significativas (*p* ajustada a 0.01) para las escalas sindrómicas de problemas sociales, quebranto de normas, trastorno internalizantes, trastornos externalizantes y total de problemas. Muy próximas a la significación se encontraban ansiedad y problemas atencionales (ver Tabla 2).

En el caso de las escalas orientadas al DSM, los resultados mostraron que existían diferencias estadísticamente significativas en entre niños desnutridos y normopeso en la escala de trastorno oposicionista y próximas a la significación la escala de trastorno de ansiedad, TDHA y estrés post-traumático (ver Tabla 2).

3. Prevalencia de los trastornos sindrómicos y del DSM en niños obesos y desnutridos.

Aplicando los puntos de corte clínicos propuestos por Achenbach y Rescorla[10], se obtuvo el porcentaje de niños desnutridos que puntuaban en el límite o en el rango clínico en los factores (T => 65), escalas Int, Ext y Tot P (T => 60). Los resultados mostraron que los mayores porcentajes de niños afectados se encontraban en las escalas de ansiedad, quejas somáticas, problemas de pensamiento, internalizantes y externalizantes para las escalas sindrómicas. Para las escalas orientadas al DSM, los mayores porcentajes se encontraban en las escalas de ansiedad, problemas somáticos, trastorno oposicionista y trastorno por estrés post-traumático (ver Tabla 3).

DISCUSION

El objetivo principal de nuestro trabajo fue estudiar la relación de la dos estados nutricios (desnutrición y normopeso) con la salud mental, utilizando el CBCL/ 6-18, escala que hace una exploración amplia de las principales psicopatologías. Para ello, primero determinamos que el grupo multicultural de referencia normativo 3, es el que se ajusta mejor a los niños mexicanos. Usando el grupo normativo 3 como grupo de referencia, encontramos que los niños desnutridos presentan alteraciones psicopatológicas.

Considerando las escalas sindrómicas, encontramos que los niños desnutridos padecían tanto trastornos internalizantes como externalizantes comparados con los niños normopeso y considerando las escalas orientadas al DSM, el trastorno oposicionista es el que diferenciaba a los grupos, seguido por trastornos de ansiedad, TDHA y estrés post-traumático.

Existen escasos trabajos que hayan estudiado la psicopatología de los niños desnutridos a pesar de las conocidas conexiones que existen entre los estados nutricionales y la psicopatología.[16,17] De nuestro conocimiento, tan sólo Liu, et al.[6] investigó el estado psicopatológico de los niños desnutridos encontrando mayor prevalencia de alteraciones externalizadoras. Nuestros datos también han encontrado problemas externalizantes como problemas sociales y quebranto de normas pero, además, ha encontrado una alta frecuencia de problemas internalizantes como problemas de pensamiento o de ansiedad. Probablemente, nuestros resultados están siendo influenciados por la situación de violencia en la que se encuentra Ciudad Juarez en el momento de la evaluación que puede estar más relacionada con el alto porcentaje de problemas internalizantes que hemos encontrado. Si observamos la frecuencia de los problemas en las escalas orientadas al DSM, se puede comprobar que los trastornos de ansiedad y estrés post-traumático son más prevalentes que los problemas de conducta. Sin embargo, esos datos no se han encontrado en los niños normopeso que se encuentran expuestos al mismo contexto y, por tanto, queda por investigar la posible interacción entre el estado nutricional y la vulnerabilidad al desarrollo de problemas psicopatológicos.

Por otro lado, nuestro trabajo ha proporcionado cifras de comparación internacionales para ubicar a los niños mexicanos en los grupos de referencia multicultural de la nueva versión del CBCL. Esto permitirá utilizar esta versión para futuras investigaciones que se desarrollen con niños mexicanos. Además, como la nueva versión incorpora nuevas escalas clínicas como el trastorno obsesivo-compulsivo y el estrés post-traumático, permitirá hacer estudios sobre estos trastornos en futuras investigaciones.

Estos resultados podrían estar limitados por el hecho de que todos los niños pertenecían a un estatus socioeconómico bajo y, por tanto, las prevalencias encontradas estén condicionadas por este factor (a pesar de que el grupo control era del mismo estatus). Otro factor es que el grupo de niños desnutridos presentaba desnutrición leve a moderada. Sin embargo, los resultados obtenidos incluso en estadios leves indicarían la posibilidad de mayores prevalencias en estadios más grave. Futuros estudios deberían comprobar esta hipótesis.

En resumen, los resultados de nuestro estudio indican que los niños desnutridos de Ciudad Juárez presentan alteraciones psicopatológicas tanto internalizantes como externalizantes.

Agradecimientos: Los autores agradecen a los directores de las escuelas en donde se realizó el proyecto, así como a las estudiantes que colaboraron en la recolección de los datos.

REFERENCIAS

1. Fondo de las Naciones Unidas para la Infancia (UNICEF). Seguimiento de los progresos en la nutrición de los niños y las madres: una prioridad en materia de supervivencia y desarrollo. Nueva York (NY): Fondo de las Naciones Unidas para la infancia, 2009.

2. McLachlan M. Tackling the child malnutrition problem: From what and why to how much and how. J Pediatr Gastroenterol Nutr 2006; 43(Supl 3): S38-46.

3. Fanjiang G, Kleinman R. Nutrition and performance in children. Curr Opin Clin Nutr Metab Care 2007; 10: 342-347

4. Caulfield LE, de Onis M¸ Blössner M, Black R. Undernutrition as an underlying cause of child deaths associated with diarrhea, pneumonia, malaria and measles. Am J Clin Nutr 2004; 80: 193-198.

5. Oddy WH, Robinson M, Amrosini GL, O´Sullivan TA, de Klerk NH, Beilin LJ, *et al*. The association between dietary patterns and mental health in early adolescence. Prev Med 2009; 49(1): 39-44.

6. Liu J, Raine A, Venable PH, Sarnoff A. Malnutrition at 3 years and externalizing behavior problems at ages 8,11 and 17 years. Am J Psychiatry 2004; 161: 2005-2013.

7. Comité Internacional para el Desarrollo y Estudio del Cuestionario para Escolares y Adolescentes Latinoamericanos con Trastorno por Déficit de Atención con Hiperactividad (CEAL-TDAH). Cuestionario para Escolares y Adolescentes Latinoamericanos con Trastorno por Déficit de Atención con Hiperactividad. Construcción, descripción del instrumento y datos sociodemográficos de la muestra. Salud Mental 2009, 32 (Supl 1): S55-S62.

8. Albores-Gallo L, Lara-Muñoz C, Esperón-Vargas C, Cárdenas JA, Pérez AM, Villanueva G. Validez y fiabilidad del CBCL/6-18. Incluye las escalas del DSM. Actas Esp Psiquiatr 2007; 35(6): 393-399.

9. Leiner MA, Balcazar H, Straus DC, Shirsat P, Handal G. Screening Mexicans for pshychosocial and behavioral problems during pediatric consultation. Rev Invest Clin 2007; 59(2): 116-123.

10. Achenbach TM, Rescorla LA. Multicultural guide for the ASEBA School-Age form & profiles. Burlington, Vt. University of Vermont. Research Center for Children, Youth & Fmailies, 2007.

11. Achenbach TM. User guide for Assesment Data Manger (ADM). Burlington, VT. University of Vermont. Research Center for Children, Youth & Families, 2007.

12. Aparicio RM, Estrada AL, Fernández C, Hernández RM. Manual de Antropometría. 2nd ed. Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, CONACYT: México, 2004.

13. Centers for Disease Control and Prevention (CDC). Percentile Data Files with LMS Values [document on the Internet]. CDC National Center for Health Stadistics [updated 2009 August 4; cited 2009 September 30]. Disponible en: http://www.cdc.gov/growthcharts/percentile_data_files.htm.

14. McLaren DS, Read WWC. Weigth/length classification of nutritional status. Lacent 1975; 2: 219-221.

15. Waterlow JC. Classification and definition of protein calorie malnutrition. BMJ 1972; 3: 566-569.

16. Lozoff B, Jimenez E, Hagen J, Mollen E, Wolf, A.W. (2000). Poorer behavioral and developmental outcome more than 10 years after for iron deficiency in infancy. Pediatrics 2000; 105 (4): E51.

17. Liu J, Raine A, Venables PH, Dalais C, Mednick SA.: Malnutrition at age 3 years and lower cognitive ability at age 11 years: independence from psychosocial adversity. Arch Pediatr Adolesc Med 2003; 157:593–600.

Tabla 1. Característiacas socio-demográficas de los niños

Variables	GNP	GD
Sexo de los niños (%)		
Niñas	51.22	56.8
Niños	48.78	43.2
Total	48.2	51.8
Edad de los niños (media y DE)	8. 65 (0.85)	9.09 (1.23)
Estatus socioeconómico		
Bajo (%)	100	100
Ejercicio físico (al menos 1 hora por semana) (%)	100	100

Nota: DE= Desviación Estándar

Tabla 2. ANOVAs de las escalas del CBCL/6-18

CBCL/6-18	GNP (M y DE)	GD (M y DE)	*t*	*p*
Ansiedad/Depresión	52.20 (5.269)	55.25 (6.172)	2.459	0.016
Aislamiento	51.39 (3.016)	53.48 (5.845)	2.089	0.041
Qujas somáticas	52.83 (4.511)	54.86 (7.312)	1.555	0.124
P. Sociales	51.98 (4.016)	55.18 (6.139)	2.868	0.005
P. De Pensamiento	52.71 (4.020)	54.32 (6.437)	1.394	0.168
P. de atención	51.49 (3.287)	53.86 (5.360)	2.482	0.015
Quebranto de normas	52.29 (4.355)	53.64 (4.473)	1.402	0.165
Conductas agresivas	51.63 (3.246)	54.64 (6.085)	2.864	0.006
Internalizadores	43.56 (10.373)	51.09 (10.909)	3.256	0.002
Externalizadores	44.66 (9.137)	51.18 (9.209)	3.276	0.002
Total de Problemas	42.80 (10.130)	50.82 (10.566)	3.564	0.001
Trastornos afectivos	52.02 (3.991)	54.70 (7.027)	2.181	0.033
Trastorno de Ansiedad	51.90 (3.993)	54.70 (6.447)	2.427	0.018
Problemas somáticos	52.59 (4.318)	55.18 (6.996)	2.074	0.042
TDAH	51.54 (3.613)	53.68 (4.992)	2.281	0.025
Trastono oposicionista	51.63 (2.736)	55.18 (6.510)	3.314	0.002
Conductas	52.85 (5.028)	54.30 (4.517)	1.393	0.167
TOC	52.07 (4.687)	54.39 (5.747)	2.025	0.046
TEPT	51.93 (4.931)	54.95 (6.823)	2.356	0.021

Nota: M= Media, DE= Desviación Estándar

Tabla 3. Porcentaje de niños que se encuentran en el límite o en rango clínico en el CBCL 6/18

CBCL/6-18	Normopeso % (n)	Desnutridos % (n)
Ans/Dep	7.31 (3)	13.63 (6)
Aislamiento	0 (0)	9.09 (4)
Qujas somáticas	0 (0)	13.63 (6)
P. Sociales	2.43 (1)	4.54 (2)
P. De Pensamiento	0 (0)	11.36 (5)
P. de atención	0 (0)	6.81 (3)
Quebranto de normas	7.31 (3)	4.54 (2)
Conductas agresivas	0 (0)	9.09 (4)
Internalizadores	9.75. (4)	18.1 (8)
Externalizadores	4.87 (2)	13.63 (6)
Total de Problemas	2.43 (1)	15.9 (7)
Escalas orientadas al DSM:		
Trastornos afectivos	2.43 (1)	9.09 (4)
Trastorno de Ansiedad	2.43 (1)	13.63 (6)
Problemas somáticos	2.43 (1)	11.36 (5)
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TEPT	2.43 (1)	13.63 (6)

Nota: n=número de sujetos

Anexo IV

Tabla 1. Característiacas socio-demográficas de los niños

Variables	GNP	GD
Sexo de los niños (%)		
Niñas	51.22	56.8
Niños	48.78	43.2
Total	48.2	51.8
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Estatus socioeconómico		
Bajo (%)	100	100
Ejercicio físico (al menos 1 hora por semana) (%)	100	100

Nota: DE= Desviación Estándar

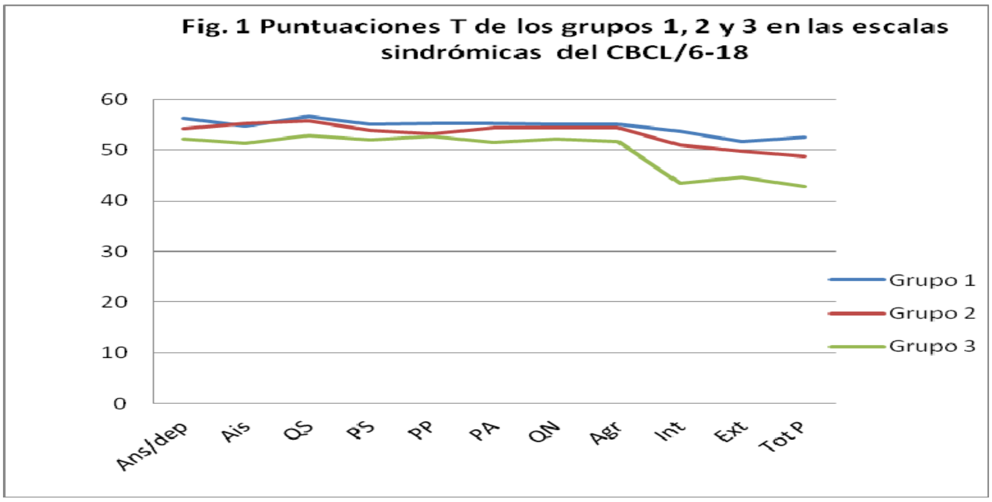
Fig. 1 Puntuaciones T de los grupos 1, 2 y 3 en las escalas sindrómicas del CBCL/6-18
60
50
40
30
20
10
0
Ans/dep
Ais
QS
PS
PP
PA
QN
Agr
Int
Ext
Tot P
Grupo 1
Grupo 2
Grupo 3

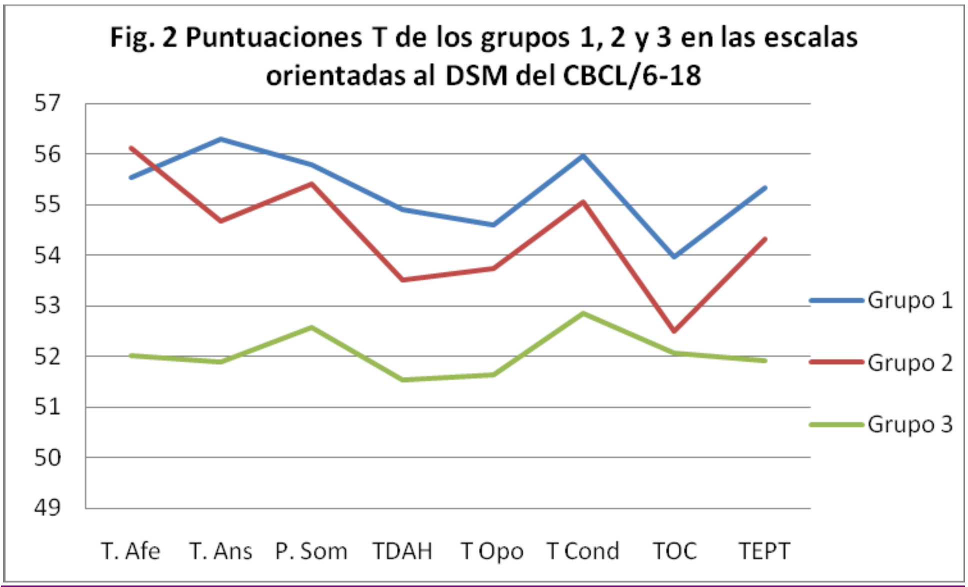
Fig. 2 Puntuaciones T de los grupos 1, 2 y 3 en las escalas orientadas al DSM del CBCL/6-18
57
56
55
54
53
52
51
50
49
T. Afe
T. Ans
P. Som
TDAH
T Opo
T Cond
TOC
TEPT
Grupo 1
Grupo 2
Grupo 3

Tabla 2. ANOVAs de las escalas del CBCL/6-18

CBCL/6-18	GNP (M y DE)	GD (M y DE)	*t*	*p*
Ansiedad/Depresión	52.20 (5.269)	55.25 (6.172)	2.459	0.016
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Externalizadores	44.66 (9.137)	51.18 (9.209)	3.276	0.002
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Conductas	52.85 (5.028)	54.30 (4.517)	1.393	0.167
TOC	52.07 (4.687)	54.39 (5.747)	2.025	0.046
TEPT	51.93 (4.931)	54.95 (6.823)	2.356	0.021

Nota: p <0.05; M= Media, SD= Desviación Estándar

Tabla 3. Porcentaje de niños que se encuentran en el límite o en rango clínico en el CBCL 6/18

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TOC	4.87 (2)	9.09 (4)
TEPT	2.43 (1)	13.63 (6)

Nota: n=número de sujetos

Anexo IV

Significant neuropsychological improvement after suplementation with omega3 in 8 -12 year Mexican malnourished children: A randomized, doble blind, placebo and case control clinical trial.

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Conflict of interest: The authors declare no conflict of interest.

Abstract:

Background: It has been shown that supplementation with omega-3 should improved the cognitive performance, especially in infants and toddlers, but it is unknown whether these results are effective in older malnourished children .

Objective: Investigate the omga-3 supplementation effects, in 8 to 12 years children and to know which neuropsychological functions improve after three months of the intervention in a sample of Mexican children with mild to moderate malnutrition.

Design: This was a randomized, double blind, placebo-controlled and case control study, 85 children age 8-12 were individually allocated to 1 of 3 groups (treatment, placebo and control). The duration of the intervention was three months. Neuropsychological performance was measured at baseline and at 3 months.

Results: In 11 of the 18 neuropsychological variables studied, more than 50% of children in the treatment group had greater improvement. And in processing speed coordination visomotor, perceptual integration, attention and executive function, that improved was present in more than 70% of supplemented children.

Conclusions: Our study show a specific effect of supplementation with omega 3 in processing speed, visoperceptive capacity, attention and the updating component of executive function. This trial was registered at clinicaltrials.gov as NCT01199120.

Introduction

Malnutrition is one of the most important nutritional issues during childhood because is in the first years of life when growth is intensive and there still is ripeness of diverse organs. Therefore, consequences will be more serious as younger is the child and more time the malnutrition last.[1]

Children malnutrition is the result of poor diet, which is related to several biological, socioeconomic and cultural factors.[2-4] In the long term, malnutrition can result of damage at cognitive functions and academic performance.[5] In addition, in the socio-economical terms, the poor countries are the most affected by the ravages of malnutrition and this hampers their development.[6]

The main nutritional deficiencies studied in children lie in the lack of protein-energy, iron and essential fatty acids deficiency;[7-9] and many of these researches tend to focus in the first two years of life, since it is -believed that brain develops intensively during those years.[10] Nevertheless, researchers have recently concluded that brain maturation has not been completed in this stage and, in addition it is not uniform[6]; on the other side, the brain development continues along the infancy, during childhood and up to the adolescence.[11,12] Therefore, cognitive and academic deficits in malnourished children during early childhood continue in late adolescence,[9] because of that, it is necessary to do researches about nutrition in posterior age since it is so that has been explored.[10]

Particularly, essential fatty acids (EFA) play an important role in learning faculties and behavior.[13,14] Deficiency of EFA significantly reduces the size of neurons in the hippocampus, hypothalamus and cerebral cortex,[7] and leads to a reduction of dopamine in the cortex area.[14] Also ω-3 deficiencies causes a significant reduction of catecholamine, which affect the transport of glucose and its use by the brain. Specifically, DHA is particularly concentrated in synaptic nerve cells where it seems to be involved in signaling processes between neuronal cells,[15] it controls the activity of neurotransmitters and the neuronal growth factors,[16] it also is a component of cerebral gray matter.[17] Although the results are controversia,l[18] it seems that DHA is crucial for normal cognitive functions.[19] Any deviation at physiological levels is associated with cognitive impairment[20] and with some developmental disorders such as attention deficit disorder, autism or motor problems.[13, 21 ,22] Overall, these variables could impact on learning performance[6]

Summarizing, most studies are characterized by: 1) making the intervention in children under three years and 2) do not make a detailed assessment of neuropsychological functions continue to develop at later ages.[9,10] Therefore, the objective of this paper is to investigate the ω -3 supplementation effects, in 8 to 12 years children and to know which neuropsychological functions improve after three months of the intervention in a sample of Mexican children with mild to moderate malnutrition. Hypothesize that the intervention group will get clinically relevant improvements in the functions related to memory and executive function as these features are mainly related to the hippocampus and the frontal lobes.

Method

Recruitment

Participants were drawn from two schools of low socioeconomic status in Ciudad Juarez, Mexico that were willing to assist with the study. The parents of children between 8 to 12 years, were invited to attended a meeting at which the study procedures were explained, written informed consent form the tutors and verbal assent form their children were obtained. In the days following, anthropometric measurements were taken to establish their nutritional status.

Participants

Yield was selected 85 children between 8 to 12 aged. These children were attending 3^{th} to 4^{th} of elementary school. In total, four were not eligible because they did not fulfill or because refused to participate, the inclusion criteria and the remaining 55 of malnourished children were randomly assigned into the study intervention groups and 26 were assigned into the control group (normal nutrition states). The demographic and clinical characteristic of the simple can see in Table 1

Inclusion and exclusion criteria

An inclusion criterion was the permission through informed consent from the primary caregiver. Like exclusion criteria were taken the presence of neurological disease (epilepsy, brain injuries, neurological syndromes detected) and hormonal diseases (diabetes or thyroid-related diseases). And were also excluded subjects who did not know to swallow pills or who have ingested the omega-3 supplement or any vitamin supplement in the last six months.

Study Design

This was a randomized, double blind, placebo-controlled and case control study. The duration of the intervention was three months, because it is the minimum time necessary to have effects on behavior and learning, [23,24] and also is the duration that conforms to standards of other studies that had supplemented with fatty acids. However, it is worth mentioning that at present there is no global consensus on the proper dosage and combination of fatty acids.[25,26] Then, the primary focus of the study was comparing the effects of parallel treatments for three months. The study was approved by the bioethics committee of the University Autonomous of Ciudad Juarez (UACJ). This trial was registered at clinicaltrials.gov as NCT01199120.

Intervention

The active treatment was a supplement containing omega-3 fish in gelatin capsules. The daily dose consist of three capsules provided ω-3 fatty acids (60 mg of DHA and 90 mg of EPA each capsule). Placebo treatment consist of soya oil capsules, were similar than the active treatment.

Treatment was administered by teachers twice daily, (one early in the morning and other at lunchtime). The afternoon capsule and the doses of weekends and holidays were administrated by the parents. Both, parents and teachers were given a calendar marked intake where they supplemented each time the child, this calendar will be delivered every two weeks. This information was completed with unused capsule counts. Baseline measures were completed and repeated at 3 months.

Measures

Anthropometric measures

Anthropometrics measurements were identified as core measures (weight and height) and anthropometric index (McLaren index, percentages of weight/age height/age and weight/height). The anthropometric measurements were performed according to specifications of the anthropometry manual from National Council for Science and Technology (CONACYT).[27] The weight was determined by a Seca ® electronic scale. The size was measured in a standing position, with the head placed so that the plane of Frankfurt was in horizontal position, a Harpenden stadimeter was used to get these measurements. All subjects were wearing light clothes and no shoes during the anthropometric data collection phase. The reference standards for weight and height were the curves and growth tables taken from the Center for Diseases Control (CDC)[28] in 2000.The cutoff points to MG was 85-95% in height/age and 70-90% in weight/height, for the NNG was 95-105 and 90-110% respectively.[29]

Omega-3 Consumption

The children's parents were asked to answer a questionnaire about the consumption frequency of food with high content of omega 3, including most consumed products offered at the local markets. The consumption was registered by rations, using the Mexican equivalents system. The content has been quantified in gr of omega 3 per each 100 gr of the aliment, in the case of fish, using the USDA lists as source of information. For high concentration of omega 3 aliments frequently used, it has been quantified according to the reported products' nutrimental labels. It has also been considered the omega 3 supplementation.

Neuropsychological measures.

The neuropsychological test battery was selected for measure the following neuropsychological domains:

- Processing Speed:
  - Symbol Search (SS). Subtest of Wechsler Intelligence Scales for Children (WISC-IV).[30] Requieres examines match symbols appearing in different groups.
- Viso-perceptive integration:
  - Embedded Figures Test (EFT). This is a subtest of the Evaluación Neuropsicológica Infantil (ENI).[31] The child is asked to find a figure as quickly and accurately as possible in a larger complex design in which it is embedded.
  - Visual Closure (VC).This is a subtest of the ENI,[31] and consists in complete visual patterns when only one or more parts of the object are presented.
- Visomotor Coordination
  - TMT A (Reitan, 1958).[32] The subject in Part A, must join with lines the numbered circles in consecutive form.
  - Block Design (BD) (WISC-IV)[30]. This test requires taking blocks that have all white sides, all red sides, and red and white sides and arranging them according to a design.
- Attention:
  - Letter Cancellation (LC) (ENI)[31]. The task consists to mark the letters "X" only when, it is preceded by the letter A in a segment with different distracter letters as fast as possible.
- Memory:

- Rey Complex Figure (REY).[33]. In which examinees are asked to reproduce a figure, first by copying and three minutes after from memory.
- Word List (WL).[31] Participants memorize a list of 12 words. The list was presented four times and participants were required to recall as many words as possible after each presentation. After half an hour, they were asked to recall the 12 original target words. Participants were then with a list of distracter words and asked to recall those. Following a filled delay, participants were again asked to recall by categories the original 12 target words.

- Language
  - Comprehension instruction (Com Inst).[31].Measure the ability to comprehend the reading, through a series of instructions.
  - Semantic fluency (animals).[31] This task consists in saying all the names of animals –reminded by the subject in a minute period. The task excluded, repeated words, or referrals as "pollo" "pollito"
- Executive Function:
  - Letter-Number Sequencing (L&N)[30]: This subtest of the WISC-IV consists in giving the subject a mixed set of numbers and letters orally and the subject has to complete two tasks. First, the subject has to arrange the numbers in ascending order orally and then arrange the letters in alpha order orally from the previously given set. Is a memory working test.
  - Matrix Reasoning (MR).[30] The purpose is to complete the picture matrix with any of the given solutions.
  - Stroop color and word test:[34] The test contains three lists. Children have to read words in the first list, say the name of colors in the second list,

and say the name and color of the printed words as quickly and as accurately as possible in 45 seconds per task in third list.

- TMT-B:[32] Shifting. In part B, Children must join circles with numbers and letters in alternative form.

- Absenteeism . Was estimated by the number of times a student not attended class in the bimester beforeanterior and afterposterior the supplementation.
- Academic performance (Acad Perf). Academic performance was the average of the ratings that the children had in the subjects of Spanish, Mathematics, History and, Geography, Science and Civic education.

Statistical Analyses.

All data were analyzed by the authors using the Statistical Package for Social Sciences (SPSS) version 15.

First, it was ensured that the groups were equally distributed among the demographic variables of the children and their mothers by chi-square test. Then, a mixed ANOVA (3x2) was conducted with the variable "group" (intervention vs placebo vs control group) and "moment" (pre-intervention vs post-intervention group) as factors. If statistical signification was reached for main effects or interactions, Sheffe post hoc comparisons were conducted to analyze between group differences. Neuropsychological variables were the dependent variables.

Cohen's Delta was obtained for all the comparisons. After that, in order to know the amount of children which reached a large improvement according to Cohen's criteria, each children was classified in three groups: 1) no improvement: if delta was between 0 and 0.5; 2) medium size improvement: if delta was between 0.51 and 0.8; and 3) large size improvement: if delta was bigger than 0.8. Chi-square analyses were conducted to know the statistical significance of the improvement frequency in each group. Statistical significance was established at 0.002 after Bonferroni adjustment.

Results

First, it was ensured that the groups were equally distributed in the demographic variables of the children and their mothers. Results showed that there were no statistically significative differences in the age IQ, absenteeism or academic performance of children. Neither were statistically significative differences in age, IQ, academic level or economical status of their mothers (see Table 1).

Neuropsychological differences between groups, before and after the intervention.

Secondly, we studied if there were differences among the three groups before and after the intervention.The results show that only the TXG improved in SS [F= 6.21; p<0.003]., BD [F= 10.67; p<0.000]., L&N [F= 3.73; p<0.029]., MR [F= 5.27; p<0.007]., LC [F= 3.69; p<0.030]., EFT [F= 7.28; p<0.001].,VC [F= 4.79; p<0.001]., Int Obj [F=4.96; p<0.010]., Stroop-color [F= 4.25; p<0.018], Acad Perf [F= 3.69; p<0.030] (see Table 2).

Effect size and percentages of improvements by group

Then we proceeded to study the size of the differences. The results showed that there were differences in Cohen's delta between the three groups of SS, EEF, VC,BD, LC and MR.

Finally, in 11 of the 18 neuropsychological variables studied, more than 50% of children in the treatment group had greater improvement according to the criteria of Cohen´s (delta> 0.8). Note that in processing speed (SS), coordination visomotor (BD), perceptual integration (EFT), attention (CL) and executive funtion (L&N and MR), that improved was present in more than 70% of supplemented children (see Table 3).

Discussion

Our study was designed to investigate the cognitive effects of omega-3 supplement in malnourished children. When the frequency questionnaire results were analyzed, they showed a poor consumption of aliments rich in omega 3. The applied tests revealed that only 8% of the children consumed a ration of fish two or more times a week, 39% one ration a week, 19% a ration every two weeks and 34% a ration a month. Of them 55% consumed only canned tuna and 13% sardines in tomato sauce. The most consumed fish were tilapia, trout, hake and salmon. The frequency of aliments enriched in omega 3 was very low, only 10% of the evaluated children revealed consumption about two or more times a week, most of them in milk. These results confirm the necessity of supplement with omega 3 fatty acids.

Our results shows omega-3 supplementation for three months has effects on some neuropsychological variables. The effects do not depend on the degree of maternal education, age or IQ of the mother considered a good predictor of child IQ.[35] It is important to note that our study was controlled by a control group and a placebo group, when most studies do not consider these variables.[36] We found significant differences between the treatment, placebo and control group before and after the intervention in processing speed (search symbol), visoperceptual integration (superimposed pictures and visual closure), visual coordination (block design) and in the executive function (matrix reasoning and working memory). In some neuropsychological skills, children with placebo have improvements, but not equally to the treatment group; we believe that being actively involved may have caused this effect.

This pattern of results shows a more widespread pattern of adverse effects related to structural[7] and another pattern of a specific effect of some brain areas. On the first pattern, our results have shown an increase in processing speed of children. This result could be explained by the effects that omega-3 has on the membrane of the neuron, the synapses and myelin.[7] In addition, similar works found the same results with the omega-3 supplementated.[36]

On the other hand, we have found benefits associated with different functions in brain areas. First, we found an improvement in visoperceptual tests. This result corroborates several studies that have shown improvement in visual processing areas after supplementation with omega 3,[37] even in new born early months.[38] However, our results would show that this improvement can be achieved in the age window selected for this study.

We have also found improvements in sustained attention, which is associated especially with the development of ADHD. In fact, previous studies have used the omega-3 supplementation for improving attentional problems of children with ADHD disorder with mixed results.[10,21] Therefore, our results would support such intervention since, at least in our sample, we found that improvement. These results are also consistent with studies indicating that omega-3 is related to the increased availability of dopamine in the brain cortex.[14]

Likewise we found a significant improvement in the update component of executive function such as abstract reasoning and working memory. These results are consistent with previous studies that have found improvements in these functions after supplementation, even though not at this age. However, we hypothesized that the high numbers of children have improved in the treatment group because the intervention was conducted in this period for this particular function. In addition, the findings on the role of omega 3 on the enhanced availability of neurons in the cortex and their role with the increased availability of dopamine as well, may explain this findings.[14]

Like many authors, we found no differences in any of the memory variables.[39] This could show the specificity of the effects of omega 3 and would suggest not using global measures of cognitive performance. Moreover, this effect is not dependent on improved processing speed since memory tests measure precision not speed. However, these results do not support our initial hypothesis that expected an improvement in memory due to previous findings on the role of omega 3 in the number of neurons in the hippocampus. Although this improvement has occurred in the intervention group also occurred in the other groups showing that memory is more sensitive to external stimulation to the effect of omega 3.

As far as we know, this is the first study of omega-3 supplementation where is considered the magnitude of change for each participant. We found large changes in malnourished children supplemented with omega-3 that were not observed in placebo malnourished children, or control children in the neuropsychological variables. These results show significant increases over 70% of children in the supplemented group and throw light on the clinical significance beyond the statistics relevance. Although no previous studies with only omega-3 supplementation in malnourished children aged 8-

12 have been carried out with, a similar study found no significant improvement postoperatively.[39] The difference in design, supplements and neuropsychological tests do not allow comparisons between these two studies.

However, these results may be limited by two factors. First, all children in the sample belonged to the same socioeconomic status and, second, all children were of a mild-moderate malnutrition.

In summary, the results of our study show a specific effect of supplementation with omega 3 in processing speed, visoperceptive capacity, attention and the updating component of executive function.

References

1. Pollitt E. A developmental view of the undernourished child: background and purpose of the study in Pangalengan, Indonesia. Eur J. Clin Nutr 2000; 52*:* s2-s10.

2. Zlotkin S. Priorities in nutritional rehabilitation. J Pediatr Gastroenterol Nutr 2006; 43: s66-s71.

3. Rivera JA, Sepúlveda J. Conclusions from the Mexican National Nutrition Survey 1999: translating results into nutrition policy. Salud Pub Mex 2003; 45: s565- s575.

4. Wachs T. Nutritional déficits and behvioural development. International Journal of Behavioral Development 2000;24: 435-441.

5. Grantham-McGregor S, Cheung YB, Cueto S, Glewwe P, Richter L, Strupp B; International Child Development Steering Group. Developmental potential in the first 5 years for children in developing countries. Lancet. 2007; 369: 60-70.

6. Branca F. Nutritional solutions to major health problems of preschool children: How to optimize growth and development. *J Pediatr Gastroenterol Nutr* 2006; 43: s4-s7.

7. Yehuda S, Rabinovitz S, Mostofsky DI. Nutritional deficiencies in learning and cognition. J Pediatr Gastroenterol Nutr 2006; 43: s22-s25.

8. Tofail F, Persson LA, Arifeen SE, et al. Effects of prenatal food and micronutrient supplementation on infant development: a randomized trial from the Maternal and Infant Nutrition Intervention, Matlab (MINIMat) study. Am J Clin Nutr 2008; 87: 704-711.

9 Walker S P, Chang S.M, Powell CA, Mgrantham-McGregor S. Effects of early childhood psychosocial stimulation and nutritional supplementation on cognition and education in growth-stunted Jamaican children: prospective cohort study. Lancet 2005;36: 1804-1807.

10. Benton D. The influence of children´s diet on their cognition and behavior. EurJ Nutr2008; 47 (3): 25-37.

11. Ito M. 'Nurturing the brian' as an emerging research field involving child neurology. Brain & Developmet 2004;2:, 429-433.

12. Romine C B, Reynolds C R. Sequential Memory: A developmental perspective on its relation to frontal lobe functioning. Neuropsychol Rev 2004; 14(1): 43-64.

13. Johnson, C.R., Handen, B. L., Zimmer, M. & Saco, K. (2010) Polyunsaturated Fatty Acid Supplementation in Young Children with Autism. J Dev Phys Disabil (2010) 22:1–10 DOI 10.1007/s10882-009-9152-x.

14. Yehuda S, Rabinovitz S, Mostofsky DI. Mixture of essential fatty acids lowers test anxiety. Nutr Neurosci 2005; 8(4): 265-267.

15. Youdim KA, Martin A, Joseph JA. Essential fatty acids and the brain: possible health implications. Int J Dev Neurosci 2000; 18: 383-399.

16. Yehuda S, Rabionovitz S, Carrasso RL y Mostofsky DI. The role of polyunsaturated fatty acids in restoring the aging neuronal membrane. Neurobiology of aging 2002; 23: 843-853.

17. Innis S. Fatty acids and early human development. Erly Hum Dev,2007; 83*:* 761-766.

18. Hirayama S, Hamazaki T, Terasawa K. Effect of docosahexaenoic acid-containing food administration on symptoms of attention-deficit/hyperactivity disorder- a placebo-controlled double-blind study. EurJ Nutr 2004; 58: 467-473.

19. Sinn N, Bryan J. Effects of supplementation with polyunsaturated fatty acids and micronutrients on learning and behavior problems associated with child ADHD. *Dev Beh Peds 2007: 28,* 82-91.

20. Yeduha S, Rabionovitz S, Mostofsky DI. Essential fatty acids are mediators of brain biochemistry and cognitive functions. J Neurosci Res1999; 56: 565-570.

21. Raz R, Carasso RL, Yehuda S. The influence of short-chain Essential Fatty Acid on children with Attention-Deficit/Hyperactivity Disorder: A doble-blind placebo-controlled study. *J Child Adoles Psychopharmacol 2009; 19* (2): 167-177.

22. Richardson A J, Ross MA. Fatty acid metabolism in neurodevelopment disorder: a new perspective on associations between attention-deficit/hyperactivity disorder, dyslexia, dyspraxia and the autistic spectrum. Prost Leukot Essent Fatty Acids 2000; 63: 1-9.

23. Kakiraluloma L, Närhi V, Ahonen T, Westerholm J, Aro M. Do fatty acids helping overcoming reading difficulties? A double-blind, placebo-controlled study of the effects of eicosapentaenoic acid and carnosine supplementation on children with dyslexia. Child are, health dev 2008; 35(1): 112-119.

24. Richardson AJ, Puri BK. A randomized double-blind, placebo-controlled study of the effects of supplementation with highly unsaturated fatty acids on ADHD-related symptoms in children with specific learning difficulties. *Prog Neuro Psych Biol Psych 2002; 26:* 233-239.

25. Richardson AJ, Montgomery P. The Oxford-Durham Study: A randomize, controlled trial of dietary supplementation with fatty acids in children with Developmental Coordination Disorder. Pediatrics 2005; 115 (5): 1360-1366.

26. Castro-González MA, Ojeda A, Silencio JL, Cassis L, Ledesma H, Pérez-Gil F. Perfil lípidico de 25 pescados marinos mexicanos con especial énfasis en sus ácidos grasos n-3 como componentes nutracéuticos. Archivos Latinoamericanos de Nutrición 2004; 54:328-336.

27. Aparicio RM, Estrada AL, Fernández C, Hernández RM, Ruiz M, Ramos D *et al.* Manual de Antropometría. 2nd ed. Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, CONACYT: México 2004.

28. Centers for Disease Control and Prevention (CDC). Percentile Data Files with LMS Values [document on the Internet]. CDC National Center for Health Stadistics [updated 2009 August 4; cited 2009 September 30]. Available from: http://www.cdc.gov/growthcharts/percentile_data_files.htm.

29. Waterlow JC. Classification and definition of protein calorie malnutrition. *BMJ* 1972; 3: 566-569.

30. Wechsler D. *Escala de inteligencia de Wechsler para Niños-IV (WISC-IV).* México: Manual Moderno 2007.

31.Matute E, Rosselli M, Ardila A, Ostrosky-Solís F. *Evaluación Neuropsicológica Infantil (ENI).* México: Manual Moderno 2007.

32. Reitan RM. Validity of the Trail Making Test as an indicator of organic brain damage. *Perc Motor Skills 1958;, 8:* 271-276.

33. Rey A. *Test de Copia de la Figura Compleja (Rey).* Madrid: Ediciones TEA 1987.

34. Golden CJ. *Stroop, Test de Colores y Palabras* (4ª ed.) Madrid: Ediciones Tea 2005.

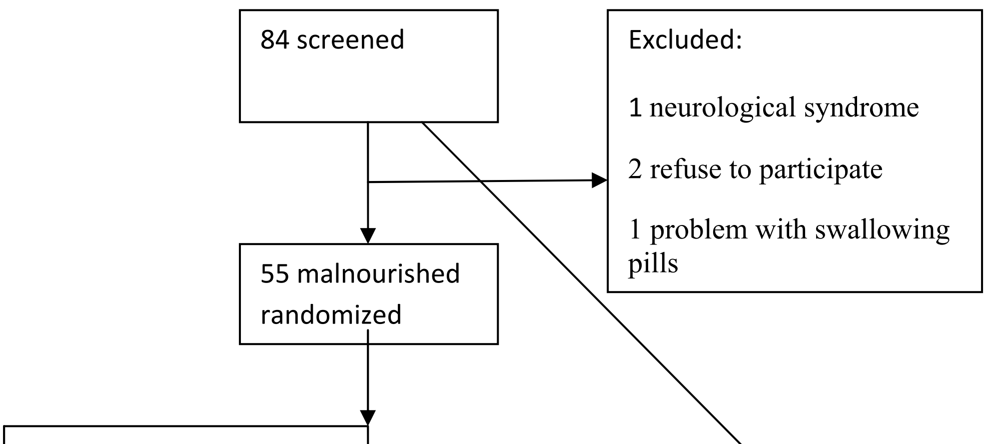
35. Menezes-Filho J A, Novaes CO, Moreira JC, Sarcinelli PN. Mergler D. Elevated manganese and cognitive performance in school-age children and their mothers. Environmental Research, 2011; 111: 156-163.

36. Cheatham CL, Nerhammer S, Asserhoj M, Michaelsen K, Lauritzen L. Effect of long- chain polyunsaturated fatty acid maternal supplementation during lactation on the executive function abilities of 7-year-olds. Lipids 2011; 46: 637-645.

37. Kirby A, Woodward A, Jackson S. Benefits of omega-3 supplementation for schoolchildren: review of the current evidence. *Br Edu Res J 2010;36 (5):* 699-732.

38. Birch E, Carlson S, Hoffman DR, Fitzgerald-Gustafson K, Fu V, Drover JR, et al. The DIAMOND (DHA intake And Measurement OF Neural Development) Study: a double-masked, randomized controlled clinical trial of the maturation of infant visual acuity as a function of the dietary level of docosahexaenoic acid. Am J Clin Nutr 2010; 91: 848-858.

39. Muthayya S, Eilander A, Transler C, Thomas T, van der Knaap H, Srinivasan K, et al. Effect of fortification with multiple micronutrients and n-3 fatty acids on growth and cognitive performance in Indian schoolchildren: the CHAMPION (children´s Health and Mental Performance Influenced by Optimal Nutrition) Study. Am J Clin Nutr 2009; 89:1766-1775.



Baseline

3month

Figure1. Flow chart of the participants

Table 1. Sociodemographics Characteristic

	Treatment group (TxG)	Placebo Group (PlG)	Control Group (CG)	*F / Chi*	*p*
Age of Mother (Mean / SD)	31.80 (4.29)	32.47 (5.00)	34.72 (5.56)	2.518	0.088
Mother's Education (%)				6.676	0.572
Elementary school	5	13.3	8		
Secondary	35	33.3	36		
High School	50	33.3	24		
Technical degree	5	16.7	20		
Bachelors degree	5	3.3	12		
Mother's IQ (Mean/SD)	84.03 (9.70)	84.42 (10.50)	84.68 (7.66)	0.340	0.967
Child IQ (Mean/SD)	87.00 (12.30)	94.25 (19.51)	90.22 (23.68)	0.735	0.484
Child Gender (%)				0.139	0.933
Female	23.07	17.94	17.94		
Male	15.38	11.53	14.1		
Total	38.45	29.47	32.04		
Child age (Mean/SD)	9.37 (1.173)	9.08 (.985)	9.06 (.944)	0.720	0.490
Social-economic status (%)					
Low	100	100	100		
Academic performance	7.328 (1.08)	7.496 (1.08)	7.992 (1.025)	1.900	0.157
Scholar absenteism	2.00 (2.259)	2.476 (3.641)	.708 (.999)	2.430	0.100
Physical activity performed (at least one hour per week) (%)	100	100	100		

Tabla 2. Differences in pre-post neuropsychological variables in treatment, placebo and control groups.

Dominie		Variable	TxG(meand and SD)		PIG (meand and SD)		CG (meand and SD)		Efecto	*F*	*p*	Post Hoc	
			Pre	Pos	Pre	Pos	Pre	Pos					
Processing Speed		Symbol Search	16.065 (4.135)	19.933 (4.456)	18.809 (6.104)	20.047 (5.267)	18.208 (4.393)	19.291 (4.227)	Pre Pos	29.23	0.000		
									PP* Dx	6.21	0.003	Placebo Tx Control	0.021 0.000 0.000
Vispoerceptual integration		Embedded Figures	10.800 (1.936)	12.300 (1.822)	10.666 (2.456)	11.000 (2.569)	11.208 (1.718)	11.083 (1.501)	Pre Pos	9.077	0.004		
									PP* Dx	7.28	0.001	Placebo Tx Control	0.391 0.000 0.671
		Visual Closure	4.233 (1.250)	5.200 (1.270)	3.809 (1.661)	4.1422 (1.621)	4.166 (0.761)	4.333 (0.963)	Pre Pos	17.311	0.000		
									PP* Dx	4.79	0.001	Placebo Tx Control	0.090 0.000 0.405
Visoconstructive integration		Block Design	21.500 (8.240)	28.333 (8.138)	22.428 (10.254)	22.571 (9.303)	20.041 (8.121)	21.500 (7.575)	Pre Pos	18.626	0.000		
									PP* Dx	10.674	0.000	Placebo Tx Control	0.876 0.000 0.252
		TMT-A	93.766 (47.342)	76.433 (44.961)	84.684 (26.119)	75.842 (33.992)	86.041 (30.240)	66.58 (22.936)	Pre Pos	14.034	0.000		
									PP* Dx	0.564	0.571		
Attention		Letter Cancellation	20.333 (7.702)	23.733 (6.329)	20.095 (8.383)	21.857 (7.882)	20.666 (6.571)	12.875 (6.641)	Pre Pos	12.704	0.001		
									PP* Dx	3.69	0.030	Placebo Tx Control	0.004 0.002 0.805
ENI: Verbal Memory		Verbal inmediatly recall	22.166 (8.530)	27.700 (5.627)	21.381 (5.142)	25.285 (5.857)	21.916 (6.013)	24.166 (4.400)	Pre Pos	20.772	0.000		
									PP* Dx	1.344	0.267		
		Verbal free recall	6.700 (2.561)	8.166 (1.743)	7.000 (2.509)	7.619 (1.774)	6.833 (1.711)	7.125 (1.776)	Pre Pos	8.028	0.006		
									PP* Dx	1.743	0.182		
		Verbal cue recall	6.833 (2.422)	8.533 (1.851)	6.904 (2.071)	8.142 (1.681)	7.250 (1.799)	7.583 (1.501)	Pre Pos	17.983	0.000		
									PP* Dx	2.599	0.081		
		Verbal recognition	20.733 (3.268)	22.066 (1.460)	21.666 (1.425)	21.714 (2.028)	20.916 (3.161)	21.125 (2.383)	Pre Pos	2.326	0.132		
									PP* Dx	2.980	0.235		
REY: Visual Memory		Visual inmediatly recall	11.433 (6.508)	14.700 (7.355)	11.023 (6.664)	10.809 (5.801)	11.854 (6.509)	10.666 (5.155)	Pre Pos	0.540	0.465		
									PP* Dx	2.842	0.065		
Languaje		Animal	10.233 (5.738)	11.600 (2.931)	9.619 (3.169)	11.000 (3.331)	10.083 (3.361)	10.333 (3.422)	Pre Pos	7.894	0.006		
									PP* Dx	1.11	0.336		
		Comprehension instruction	7.483 (1.600)	8.283 (1.498)	7.857 (1.074)	8.428 (1.154)	7.875 (1.200)	8.125 (1.141)	Pre Pos	17.923	0.000		
									PP* Dx	1.868	0.162		
Executive Function	Reasoning	Matrix Reasoning	11.966 (4.139)	14.033 (3.782)	12.523 (3.515)	13.095 (3.448)	13.833 (4.187)	13.666 (4.400)	Pre Pos	7.467	0.008		
									PP* Dx	5.27	0.007	Placebo Tx Control	0.343 0.000 0.761
	Working memory	Letter-Number Sequencing	9.633 (5.404)	12.366 (3.498)	9.523 (4.812)	10.809 (4.308)	10.291 (6.701)	9.875 (4.386)	Pre Pos	5.962	0.017		
									PP* Dx	3.73	0.029	Placebo Tx Control	0.019 0.002 0.689
	Shifting	TMT-B	190.037 (74.369)	171.888 (55.339)	184.294 (85.866)	173.058 (88.387)	202.523 (100.339)	185.666 (80.801)	Pre Pos	1.505	0.224		
									PP* Dx	0.027	0.974		
	Inhibition	Stroop Word	60.300 (14.506)	64.733 (13.449)	56.66 (15.589)	59.000 (16.136)	56.041 (16.543)	61.750 (10.147)	Pre Pos	4.949	0.290		
									PP* Dx	0.252	0.778		
		Stroop Color	44.566 (10.624)	48.533 (9.821)	43.523 (9.790)	40.857 (9.079)	42.250 (6.495)	45.333 (7.148)	Pre Pos	2.223	0.140		
									PP* Dx	4.251	0.018	placebo TX Control	0.109 0.021 0.092
		Stroop Color-Word	22.566 (5.411)	27.260 (6.979)	23.333 (5.121)	24.381 (4.609)	23.791 (6.560)	24.916 (5.625)	Pre Pos	10.185	0.002		
									PP* Dx	3.049	0.054		
Absenteeims			2.000 (2.259)	1.366 (1.629)	2.476 (3.641)	1.619 (1.283)	.708 (.999)	1.041 (.708)	Pre Pos	13.753	0.057		
									PP* Dx	3.699	0.390		
Academic performance			7.328 (1.087)	7.900 (0.944)	7.496 (1.083)	7.919 (1.163)	7.992 (1.025)	8.054 (1.014)	Pre Pos	18.838	0.000		
									PP* Dx	3.699	0.030	Placebo Tx Control	0.011 0.000 0.695

Table 3. Means, standard deviations and % of children by groups with delta > 0.8 in each neuropsychological variables

Dominio		Variable	TxG (Mean and SD)	PIG (Mean and SD)	CG (Mean and SD)	*F*	*p*	Sheffee	% of children with delta > 0.8 TxG %(n)	PIG %(n)	CG %(n)
Processing Speed		Symbol Search	0.900 (0.868)	0.264 (0.482)	0.251 (0.785)	6.576	.002	a	77.27 (17)	9.09 (2)	13.63(3)
Vispoerceptual integration		Embedded Figures	0.834 (0.733)	0.014 (0.424)	0.185 (0.775)	10.768	.000	a	77.27 (17)	4.54 (1)	21.05 (19)
		Visual Closure	0.767 (0.896)	0.203 (0.521)	0.193 (1.117)	3.657	.031	b	38.88 (7)	16.66 (3)	44.44 (8)
Visoconstructive integration		Block Design	0.834 (0.733)	0.014 (0.424)	0.185 (0.775)	10.768	.000	a	77.27 (17)	4.54 (1)	21.05 (19)
		TMT-A	0.375 (.825)	-0.294 (0.832)	-0.731 (1.313)	1.217	.302		20 (1)	40 (2)	40(2)
Attention		Letter Cancellation	0.484 (0.759)	0.216 (0.308)	0.031 (0.618)	3.681	.030	b	77.77 (7)	11.11 (1)	11.11 (1)
ENI: Verbal Memory		Verbal inmediatly recall	0.781 (1.142)	0.710 (1.101)	0.431 (1.402)	.586	.559		45.45 (15)	21.21 (7)	33.33 (11)
		Verbal free recall	0.681 (1.301)	0.289 (0.939)	0.167 (1.225)	1.397	.254		48.27 (14)	24.13 (7)	27.58 (8)
		Verbal clue recall	0.795 (1.134)	0.660 (0.857)	0.202 (1.426)	1.803	.172		53.57 (15)	25 (7)	21.42 (6)
		Verbal recognition	0.564 (1.315)	.027 (0.887)	0.075 (1.324)	1.600	.209		55.55 (10)	16.66 (3)	27.78 (5)
REY: Visual Memory		Visual inmediatly recall	0.471 (1.117)	-0.034 (0.969)	-0.203 (1.295)	2.582	.083		50 (8)	25 (4)	16 (4)
Languaje		Animal	0.315 (0.639)	0.424 (0.839)	0.073 (1.058)	1.036	.360		30 (6)	45 (9)	20.83 (5)
		Comprehension instruction	0.516 (0.686)	0.513 (0.955)	0.195 (0.951)	1.135	.327		33.33 (9)	37.03 (10)	29.62 (8)
Executive Function	Reasoning	Matrix Reasoning	0.521 (0.618)	0.164 (0.773)	-0.038 (0.616)	4.944	.010	b	70 (7)	30 (3)	0 (0)
	Working memory	Letter-Number Sequencing	0.614 (1.011)	0.282 (0.505)	-0.075 (0.908)	4.246	.018	b	66.66 (10)	13.33 (2)	20 (3)
	Shifting	TMT-B	0.279 (1.250)	-0.129 (1.114)	-0.186 (1.333)	.082	.921		30(3)	30(3)	40 (4)
	Inhibition	Stroop Word	0.317 (1.130)	0.147 (0.790)	0.427 (1.404)	.337	.715		52.38 (11)	14.28 (3)	33.33 (7)
		Stroop Color	0.387 (0.873)	-0.282 (0.772)	0.450 (1.259)	3.797	.027	d	42.10 (8)	10.52 (2)	47.37 (9)
		Stroop Color-Word	0.747 (1.100)	0.215 (0.892)	0.187 (1.053)	2.556	.085		50 (12)	20.83 (5)	29.17 (7)
Academic performance			0.0751 (0.084)	0.054 (0.089)	0.007 (0.094)				N/A	N/A	N/A

Note: a= TX> (Placebo = control); b= Tx > Control; Placebo = TX y control; c= TX > placebo; control = tx y placebo;d= tx= plcebo= control.