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Original research

Trajectories of osteogenic physical activity in children and adolescents: A 3-year cohort study

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ABSTRACT

Objectives: We explored the latent profiles based on locomotor skills and cardiorespiratory fitness in Finnish schoolchildren and examined their associations with latent growth curves of osteogenic physical activity (PA) over three years.
Design: Prospective cohort study.
Methods: Altogether 1147 Finnish adolescents aged 11–13 years participated in the study. Osteogenic PA in terms of osteogenic index (OI) was calculated based on acceleration peak histograms using all of the peaks with acceleration > 1.3 g. Locomotor skills were assessed using the five-leap and side-to-side jumping tests and cardiorespiratory fitness (CRF) using 20-metre shuttle run test. The latent growth curve models for the locomotor skills and cardiorespiratory fitness profiles were tested to examine the longitudinal development of OI scores over time three years (from T0 to T3).
Results: OI scores were lower amongst children in the “Low locomotor profile” compared with “Moderate” and “High locomotor” profiles. The OI scores linearly decreased from T0 to T3 in each locomotor profile and the decrease was similar in all the profiles. Moreover, OI scores were lower in the “Low CRF profile” compared with “Moderate” and “High CRF” profiles. The OI scores decreased in each profile over time, but the decrease was steepest in the “Low CRF profile”, whereas “Moderate” and “High CRF profiles” had similar developmental trajectories.
Conclusions: Children with the highest locomotor skills and higher CRF accumulate more osteogenic PA than their least skilful and fit peers, which can have important implications on bone health in this critical period for bone growth.

Practical implications

- Although the effects of high-impact physical activity on bone health in children and adolescents are well-established, there is a knowledge gap on the trajectories of bone-strengthening physical activity and the identification of those with lower levels of bone-strengthening physical activity.
- Bone-strengthening physical activity decreased during the three-year follow-up and therefore bone-strengthening physical activity should be actively promoted.
- The decrease in bone-strengthening physical activity was largest and steepest amongst those with low cardiorespiratory fitness.

1. Introduction

The current physical activity (PA) guidelines emphasise accumulating moderate-to-vigorous PA to ensure several health benefits varying from cardiometabolic to brain outcomes.[1] The guidelines also advocate bone- and muscle-strengthening activities thrice a week.[1] However, the recommendation may be challenging to operationalise, particularly in the case of the bone-strengthening part, due to a lack of identifying concrete weekly targets, such as the number of jumps. This knowledge gap is particularly concerning as insufficient levels of bone-strengthening PA may increase the risk of osteoporosis later in life.[2] Therefore, there is an urgent need for evidence on the levels, trajectories, and

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determinants of bone-strengthening PA that can be utilised in planning effective and practical interventions in youth.

Modifiable lifestyle factors are crucial contributors to peak bone mass,[3] with the growth spurt around the circumpubertal years presenting a particular window of opportunity for optimising the adult peak bone mass.[4] PA-induced loading, along with adequate nutrition, is an essential stimulus for optimising bone development in children and adolescents.[3,5,6] However, little is known about the determinants of osteogenic (bone growth-facilitating) PA during adolescence.

Previous studies investigating the relationship between habitual PA and bone health have focussed primarily on moderate to vigorous and vigorous-intensity PA, using cutoffs developed to quantify energy expenditure.[7,8] These studies have also utilised relatively long analysis epochs from several seconds to a minute. The use of seconds-long summary epochs impairs the ability to capture the transient impact peaks that trigger the molecular cascade leading to bone growth.[9] For example, jumping improves bone health,[6] but it is often omitted in analyses using traditional cutoffs and ≥15-second epochs.[10] Therefore, we argue that osteogenic PA metrics should be based on capturing the individual impact peaks when assessing osteogenic PA.[7] According to our argument, vigorous intensity PA identified using 1–5 s epochs[8] has been found to have meaningful associations with bone health. However, bone responds to mechanical overload rather than overall PA volume or energy expenditure,[2] and hence investigating the number and intensity of impacts using osteogenic indices (OIs) based on high-intensity acceleration peaks would map better onto the mechanobiology of bone adaptation[9] than measuring time spent in different energy-expenditure-derived intensity categories.[11] OIs have been positively associated with bone health in adults.[11,12] However, the evidence on the associations between OIs and bone health in youth is limited. Nevertheless, we have previously found that OI is more strongly associated with bone traits than moderate-to-vigorous PA in adolescents.[13]

Muscle strength and locomotor skills have also been positively associated with bone health in youth.[14–17] Furthermore, those with better locomotor skills are often more physically active than less skilful youth.[18] Due to bones being loaded in high-effort activities such as jumping, it is plausible that muscle strength and locomotor skills are determinants of osteogenic PA.[16] However, there are no previous longitudinal studies on the associations between muscle strength, locomotor skills, and osteogenic PA in youth. Furthermore, higher cardiorespiratory fitness is associated with better cardiometabolic health[19] and higher PA levels.[18] However, little is known whether youth with higher cardiorespiratory fitness also accumulate more osteogenic PA than other youth. Thus, it is essential to understand the long-term trajectories of osteogenic PA.

Although the effects of high-impact PA on bone health in children and adolescents are well-established, there are no previous studies on the trajectories of specific osteogenic PA and the identification of those with lower levels of osteogenic PA. Without an understanding of the determinants of osteogenic PA and typical levels of osteogenic PA in the population, it is impossible to identify those at risk of insufficient levels of bone-strengthening activity. This study is the first to explore the latent profiles based on locomotor skills and cardiorespiratory fitness in Finnish school-aged youth and examine their associations with latent growth curves of OI to address these knowledge gaps.

2. Methods

The participants were 1147 (girls 582, boys 565) Finnish school-aged youth aged 11–13 ($M = 11.27 \pm 0.33$ years) at baseline. Of them, 564, 591, 336, and 239 had valid accelerometer data for OI at baseline, 1-year follow-up, 2-year follow-up, and 3-year follow-up, respectively. They were selected from 35 public schools in Southern (46 % of students), Central (40 %), Eastern (7 %), and Northern Finland (7 %). The invitations were sent to all 5th-grade children through school principals. The schools were Finnish-speaking comprehensive schools with approximately 300–500 students following the national core curriculum. Although equal opportunity for participation was offered to all youth, no youth with disabilities or special needs participated. The Human Sciences Ethics Committee of the University of Jyväskylä approved the study protocol. The parents or caregivers of the youth gave their written informed consent, and the youth gave their verbal assent to participation. The data were collected using equal procedures from T0 to T3 (August to September) from 2017 to 2020 (Fig. 1). Locomotor skills and cardiorespiratory fitness were assessed before the accelerometers were distributed to the participants.

Osteogenic PA was evaluated from the multiple-day accelerometry records using our in-house Java and Matlab implementation as we have done in previous publications, e.g.[13] Briefly, the magnitude (Euclidian norm) of the resultant acceleration was calculated for each sample and was used for subsequent analysis. Each continuous peak above 1.3 times gravitational acceleration (g) was identified, and the timestamp and the maximum value of the peak were noted. The peaks were divided into a 32-bin histogram[11] in non-overlapping 24 h epochs starting from the first midnight of the recording. Non-wear was estimated based on 5 s non-overlapping epoch mean amplitude deviation (MAD). All continuous bouts of at least 20 min duration below 0.0042 g MAD were set to non-wear and days with at least 8 h of wear were included in subsequent analyses. At least three included days in a given time point were required to include the data for the specific measurement wave. The daily peak histograms of the included days were then summarised by multiplying the lower bin threshold (e.g. 1.3 g) with the natural logarithm of the peaks that fell into that bin plus one (e.g. $\ln(\text{peak number} + 1)$, where peak number $=$ 4321). The products of the bin threshold and natural logarithm of the peak number were summed over the 32 histogram bins to produce an OI for the 24 h epoch (day), and the mean of all the days on record at a particular measurement time point was used to indicate the osteogenic PA (OI score) for a particular individual at the measurement time point (e.g., T0). We have previously showed that OI computed using the same method is positively associated with bone traits assessed by peripheral quantitative computed tomography amongst adolescents.[13] Moreover, the OI has been found to be prospectively associated with bone traits in women.[11]

Locomotor skills were assessed using the 5-leap and the side-to-side jumping tests. In the 5-leap test, participants completed five consecutive horizontal leaps, and the distance was measured in centimetres. The leaping sequence started in a standing position with feet together. After the first leap, the participant continued by taking four strides with alternating legs and landed with both feet parallel. The distance was measured from the toe-line of the starting position to the back of the heel in the end position. A better score out of two attempts was recorded. In the side-to-side jumping test, participants were asked to jump sideways over a small wooden beam as quickly as possible for 15 s. Whilst jumping sideways, participants were instructed to keep their feet together. The result was a sum score of two trials. Both tests have been previously used amongst Finnish adolescents with adequate test–retest intraclass correlations (five-leap: 0.84 and side-to-side jump: 0.51).

Cardiorespiratory fitness was assessed using the 20-metre shuttle run test. Participants were asked to run back and forth between two parallel lines 20 m apart. The frequency of the pre-recorded audio signal determined the running pace for each 20-metre shuttle. The initial running velocity was 8.5 km/h for the first minute, after that, the running velocity increased 0.5 km/h per minute. The participants continued until they could not keep pace. The final score was the number of laps completed whilst keeping to the pace of the signals. The 20-metre shuttle run test has been shown to be an appropriate field-based measure of cardiorespiratory fitness in children and adolescents (see further details in Supplementary Digital Content).

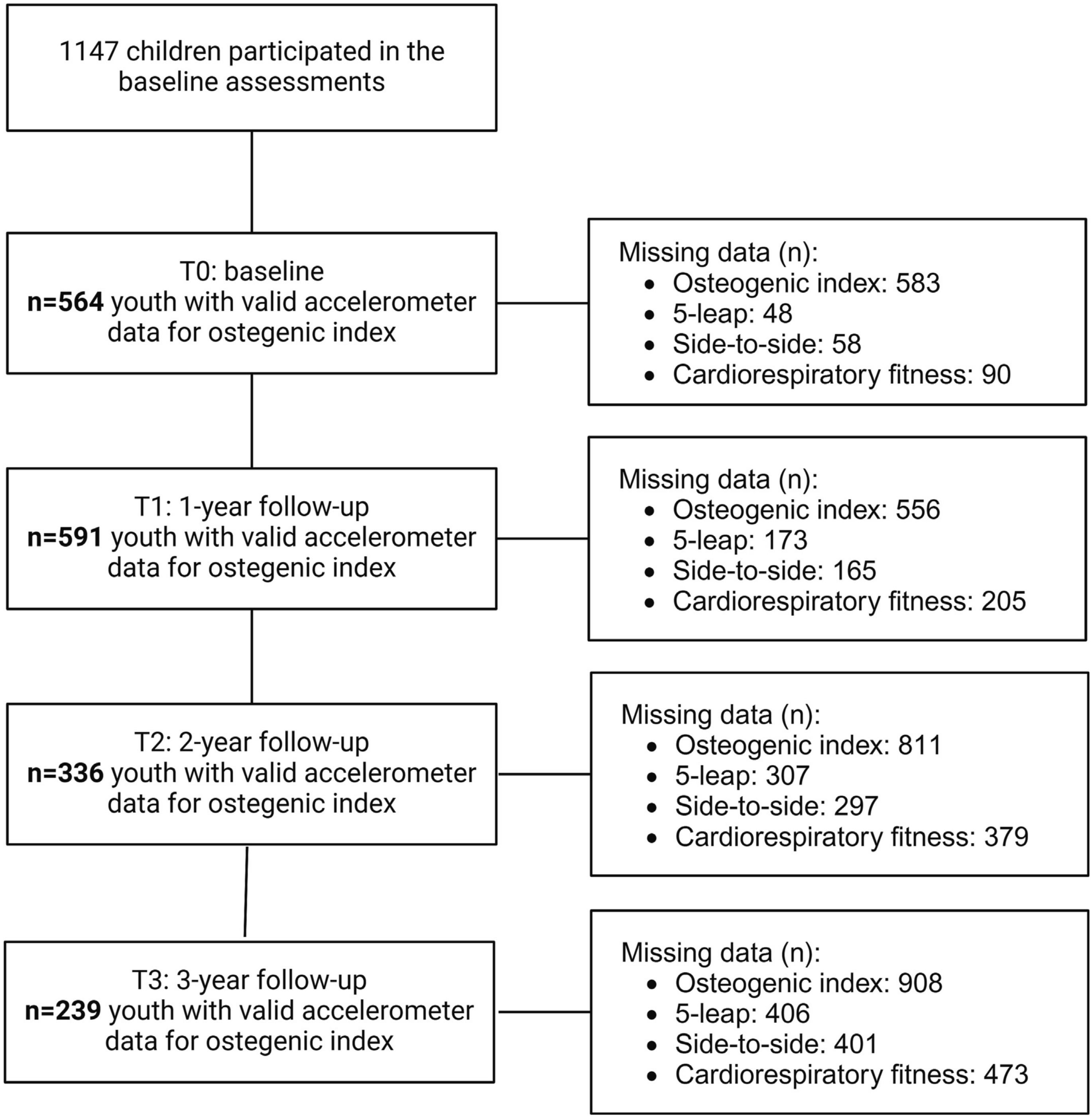

Fig. 1. Flow chart of the study.

Body height and weight were measured using calibrated instruments. BMI was calculated using the height and weight formula (kg/m^2). For each participant, an average BMI value from T0 to T3 was used in the analyses.

Somatic maturity status in terms of peak height velocity (PHV) and age at PHV was determined from the repeated height measurements at the assessment time points by using the natural spline method (Supplementary Digital Content).

Descriptive statistics, including participants, minimum and maximum, mean, and standard deviations of observed variables, were examined. Due to a dropout from the study over three years, there were missing data for locomotor skills and cardiorespiratory fitness. Furthermore, some participants did not wear the accelerometer for a valid period. The Missing Completely at Random test (MCAR) indicated that the OI data with and without missing scores were equal ($X^2(28) = 29.70$, $p = 0.378$). Based on this, the missing values were not expected to be biased and the data required no further modifications for the main analyses. Next, the latent profiles based on the locomotor skills (5-leap and side-to-side) and cardiorespiratory fitness were identified using the Latent Profile Analysis (LPA). The most reasonable model fit was estimated based on indices of the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), sample-size adjusted BIC (ABIC), Adjusted Lo–Mendell–Rubin likelihood ratio test (ALMR-LRT), profiles sizes, and entropy. Lower AIC, BIC, and ABIC and higher entropy indicated the most reasonable model fit. The ALMR-LRT test compared the estimated model K and alternative model K-1 including one profile

Table 1
Descriptive characteristics.

	T0					T1					T2					T3				
	N	Min	Max	M	SD	N	Min	Max	M	SD	N	Min	Max	M	SD	N	Min	Max	M	SD
Age (years)	1118	10.7	12.6	11.3	0.3	1118	11.7	13.7	12.3	0.3	1118	12.7	14.7	13.3	0.3	1118	13.7	15.7	14.3	0.3
Height (cm)	1120	126.5	172.0	148.1	7.0	1022	130.0	176.0	154.4	7.5	861	136.0	185.4	161.2	7.7	667	144.0	194.0	166.1	8.1
Weight (kg)	1121	24.9	95.4	41.7	9.1	1022	26.7	111.3	47.0	10.4	839	29.6	106.6	53.0	10.8	652	33.6	119.9	58.1	11.2
BMI (kg/m^2)	1120	13.5	36.4	18.9	3.1	1021	13.9	38.5	19.6	3.4	839	14.5	36.0	20.3	3.4	648	14.4	36.5	21.0	3.5
BMI-z-score	1120	−1.71	5.60	0.0	1.0	1021	−1.67	5.56	0.0	1.0	839	−1.67	5.56	0.0	1.0	648	−1.97	4.59	0.0	1.0
5-leap (m)	1099	3.7	10.1	7.7	0.9	974	4.4	10.9	8.2	1.0	840	5.5	11.6	8.6	1.1	741	3.0	12.8	9.0	1.2
Side-to-side (n)	1089	11	56	37.3	6.5	982	12	62	40.0	6.9	850	16	62	44.4	7.1	746	10	64	46.4	7.5
Cardio-respiratory fitness	1057	1	94	36.1	18.3	942	3	112	40.5	20.4	768	1	103	39.1	19.7	674	1	106	44.1	22.0
Osteogenic index	564	177.6	653.8	417.5	81.4	591	119.3	633.9	382.0	88.6	336	89.3	665.8	315.9	92.4	239	103.8	638.8	301.6	98.9

The data are number of participants, minimum (min) and maximum (max) values, mean (M), and standard deviation (SD). BMI, body mass index; BMI-SDS, body mass index z-score; cardiorespiratory fitness, laps completed in the 20-metre shuttle run test.

less than the current model. A statistically significant model indicated the retention of the estimated model. Profiles that included <5 % of participants were not accepted. A series of one-way ANOVA post hoc tests were conducted to test significant mean differences between profiles.

The latent growth curve models for the locomotor skills and cardiorespiratory fitness profiles were tested to examine the longitudinal development of OI scores over time. The between-group (school) differences in the observed OI scores were examined using intraclass correlations (ICC). Latent level and slope variables based on the observed variables at T0–T3 were estimated. The latent level variables referred to the initial baseline OI scores. The latent slope variables defined the growth of OI compared to the initial level. The default models for the repeated OI measures were constructed by fixing the loadings of the latent variables to one on the initial level and to zero–four on the slopes. The model fit was assessed using the Chi-square test ($\chi^2 > 0.05$), the root mean square error of approximation (RMSEA ≤ 0.06), the standardised root mean square residual (SRMR ≤ 0.08), the comparative fit index (CFI > 0.95), and the Tucker-Lewis index (TLI > 0.95). The covariate effects of sex, BMI, and PHV of the latent level and slope on OI scores were tested. These covariates were chosen a priori based on previous evidence that they are associated with PA levels and influence PA assessment.[20–22] In addition, the equality of means between locomotor and cardiorespiratory fitness was tested using a series of Wald's tests of parameter equality. The analyses were completed using Mplus version 8.8.

3. Results

Descriptive statistics of the observed variables with sample sizes, minimum and maximum values, means, and standard deviations at each time point are presented in Table 1. The latent profile analysis is presented in Supplementary Digital Content.

The model with growth curves for Low, Moderate, and High locomotor profiles including the covariates of sex, BMI, and PHV showed an acceptable fit to the data ($\chi^2(31) = 35.14$, $P = 0.278$, $CFI = 0.98$, $TLI = 0.96$, 90 % CI = 0.00–0.08, $RMSEA = 0.033$, $SRMR = 0.086$). The covariate effects were negligible, only the sex variable had a weak association with the OI level in the Low locomotor profile ($\beta = 0.41$, $SE = 0.20$, $P < 0.05$) and the High locomotor profile ($\beta = 0.28$, $SE = 0.12$, $P < 0.05$) and the OI slope in the Moderate locomotor profile ($\beta = 0.46$, $SE = 0.18$, $P < 0.05$), indicating that girls had lower OI levels and a steeper decrease than boys. Because the squared multiple correlations for latent levels and slopes were insignificant, the covariates were excluded. The modified model included the separated OI level and slope variables for each profile in the same model. The model showed an excellent fit for the data ($\chi^2(13) = 19.31$, $P = 0.114$, $CFI = 0.97$, $TLI = 0.96$, 90 % CI = 0.00 to 0.09, $RMSEA = 0.049$, $SRMR = 0.063$). The results showed that the OI level was the highest in the High locomotor profile, the higher locomotor skills, the higher OI. The OI scores decreased in each profile over time and the decrease was similar in all the profiles (Supplementary Table S4). The OI mean scores of each locomotor profile linearly

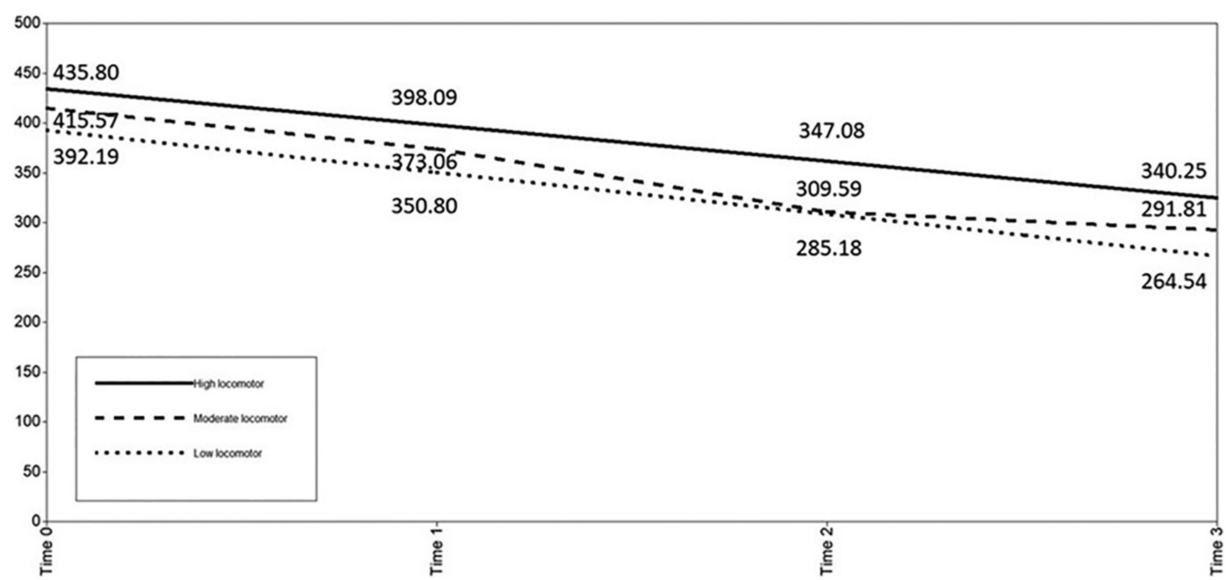

Fig. 2. Mean osteogenic index scores by locomotor skill profiles from T0 to T3 (baseline and annual assessment points).

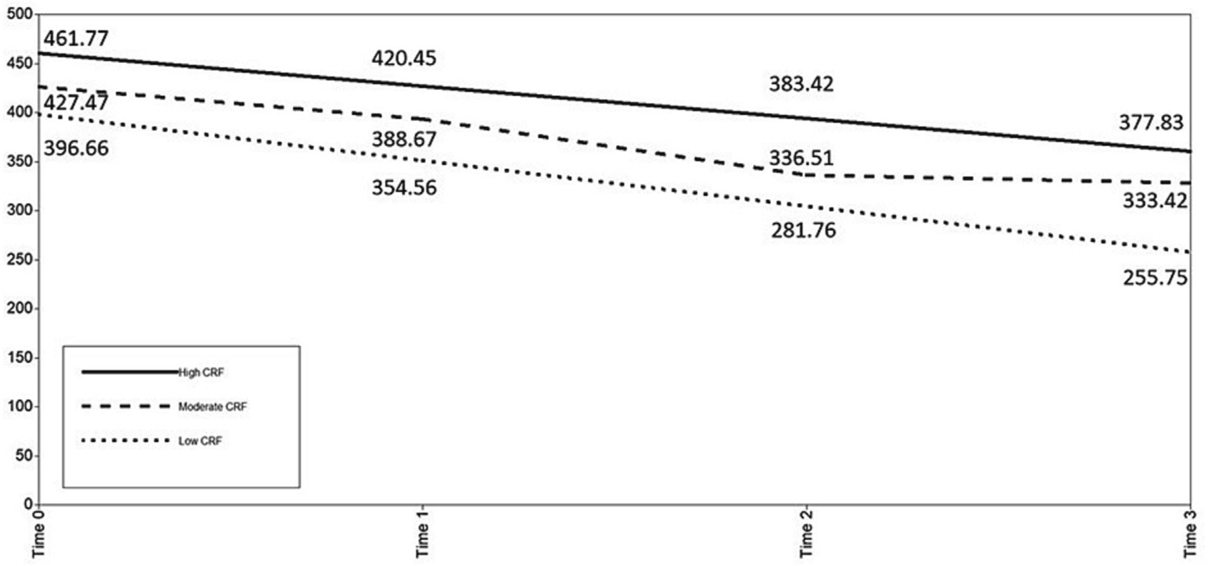

Fig. 3. Mean osteogenic index scores by cardiorespiratory fitness profiles from T0 to T3 (baseline and annual assessment points).

decreased from T0 to T3, but the OI mean scores showed a plateau between T2 and T3 in Moderate locomotor profile (Fig. 2).

The latent growth curve model examined the longitudinal development of OI through the latent levels and slopes between the CRF profiles (Low, Moderate and High) from T0 to T3. The intraclass correlations indicated that the OI scores were similar between schools (Supplementary Table S5). The theorised growth model including the covariates of sex, BMI, and PHV showed an acceptable fit to the data ($\chi^2(56) = 69.58$, $P = 0.105$, $CFI = 0.93$, $TLI = 0.90$, 90 % CI = 0.00 to 0.07, $RMSEA = 0.045$, $SRMR = 0.192$). The covariate effects were negligible, only the sex variable was weakly associated with the OI slope in the Moderate CRF profile ($\beta = 0.34$, $SE = 0.13$, $P < 0.01$), indicating that girls had a marginally steeper decrease in OI than boys. In addition, the squared multiple correlations were insignificant, showing that the model was not explaining the variance of the latent OI scores. Thus, the modified model included the separated OI level and slope variables for each profile in the same model without insignificant covariate effects. The modified model showed a good model fit for the data ($\chi^2(13) = 20.70$, $P = 0.079$, $CFI = 0.96$, $TLI = 0.94$, 90 % CI = 0.00–0.09, $RMSEA = 0.055$, $SRMR = 0.059$). The results showed that the OI level was the highest in the High CRF profile, indicating the higher CRF, the higher OI. The OI scores decreased in each profile over time and the decrease was steepest in the Low CRF profile, whereas Moderate and High CRF profiles had similar developments (Supplementary Table S4). However, the results indicated a plateau in decrease of OI in Moderate cardiorespiratory fitness profile (Fig. 3). The OI mean scores of each CRF profile linearly decreased from T0 to T3 (Fig. 3).

4. Discussion

We investigated the longitudinal trajectories of accelerometer-derived osteogenic PA across three years in a relatively large sample of youth from different regions across Finland followed from late childhood to adolescence. We found that youth with either the highest locomotor skills or the highest cardiorespiratory fitness accumulated a higher OI than those with lower levels of locomotor skills or cardiorespiratory fitness. Furthermore, whilst osteogenic index scores decreased in all locomotor and cardiorespiratory fitness profiles, the decrease was largest and steepest in the low cardiorespiratory fitness profile.

Whilst not directly comparable, our observations on the declining OI with age align with previous studies showing an age-related decline in muscle strengthening and aerobic-type PA in youth.[23] However, there is currently limited evidence regarding the optimal level of OI-based PA for promoting bone health in children and adolescents. Nevertheless, existing studies suggest that insufficient levels of muscle strengthening[24,25] and vigorous PA[24] may negatively impact bone health. Traditional methods of assessing muscle-strengthening PA and accelerometer-derived vigorous PA do not fully capture the osteogenic potential of habitual PA, particularly activities involving jumping and other high-impact movements.[8,10] Thus, using specific impact scores, our study provides more direct estimates of osteogenic PA during daily life over three years.

Consistent with previous findings demonstrating a positive association between physical fitness and moderate-to-vigorous PA accumulation in youth,[26,27] we discovered that adolescents with better locomotor skills and cardiorespiratory fitness had higher OI scores. PA, fitness, and body composition interact closely with bone health,[28] suggesting that the positive association between locomotor skills and bone health may be partially explained by the fact that adolescents with higher muscle strength and better locomotor skills engage in more osteogenic PA.[14,15] Moreover, higher levels of osteogenic PA amongst adolescents with better locomotor skills and cardiorespiratory fitness may also be due to their higher levels of overall PA.[18] In contrast to studies showing that motor competence has been found to have stronger associations with bone health traits in boys,[17,29] our study revealed that girls with poor locomotor skills experienced a slightly steeper decline in OI than other girls. Whilst the reason for these divergent findings needs to be clarified, and the studies are not directly comparable, our findings highlight the importance of targeting interventions to increase osteogenic PA in girls with low locomotor skills.

Although previous studies have not consistently observed a strong association between cardiorespiratory fitness and bone health in youth,[15,30] our results showed a positive association between cardiorespiratory fitness and OI. Additionally, Torres-Costoso et al.[28] reported an inverse association between cardiorespiratory fitness and bone health. However, their findings suggest that when controlling for factors such as adiposity and vigorous PA, children with higher fitness levels may have slightly greater bone mineral content than those with lower fitness levels. It is plausible that children and adolescents with higher cardiorespiratory fitness accumulate more osteogenic PA over their lifetime, as higher cardiorespiratory fitness has been linked to better bone health in adults.[31,32] Moreover, we observed the sharpest decline in OI amongst adolescents with the lowest cardiorespiratory fitness profile, potentially due to their overall lower levels of PA and participation in high-impact activities.[33]

Osteoporosis markedly increases the risk of bone fractures, which poses a significant personal and economic burden worldwide, affecting a considerable number of individuals.[34] PA in childhood and adolescence can be considered one of the primary interventions in the prevention of osteoporosis by enhancing bone mass, thereby reducing the risk of osteoporosis in later life.[2,34] Previous findings suggest that OI has a clinical significance in the assessment of exercise-induced changes in bone health in adults.[11] Therefore, it is important to provide children and adolescents high-impact activities to enhance bone health.[5,6] In this context, the OI could be a useful and important tool to assess the osteogenic potential of their everyday activities. Moreover, our study suggests that promoting locomotor skills and cardiorespiratory fitness, particularly in youth with the lowest levels of locomotor skills and cardiorespiratory fitness since childhood, is essential to promote osteogenic PA and, thereby, bone health, potentially contributing to the prevention of osteoporosis. Although our study did not directly measure bone health, previous research has shown that increased high-impact PA and vigorous PA benefit bone health in youth.[7,35,36]

The strength of our study includes a relatively large sample of youth follow-up for three years from late childhood to adolescence. Using the evidence that accelerometers can predict ground reaction forces meaningful to bone traits,[10,37] we used a precise analysis of accelerometer-derived data to quantify osteogenic PA using the OI. Although we quantified locomotor and cardiorespiratory fitness profiles using validated tests, it should be kept in mind that other measures of locomotor skills and physical fitness, such as running, balancing, or directly measured maximal oxygen uptake, may have provided different results. Moreover, the test–retest reliability of jumping sideways was poorer than for 5-leap, which may have a minor effect on our longitudinal results. Whilst we investigated the trajectories of osteogenic PA, the actual bone health was not assessed in the present study. Therefore, future studies are warranted to investigate whether bone density and mineral content develop in line with the osteogenic PA trajectories described in this study. Finally, as our study was observational, a bi-directional nature of the associations between locomotor skills, cardiorespiratory fitness, and osteogenic PA should be considered.[26,38] Therefore, causal interpretations should be made cautiously and tentatively.

In conclusion, adolescents with better locomotor skills and higher cardiorespiratory fitness accumulate more osteogenic PA than their less skilful and fit peers across three years. Moreover, our observations suggest that the decline over three years is largest amongst girls with the lowest locomotor skills and cardiorespiratory fitness. This warrants further investigations as such girls may be at an increased risk of osteoporosis later in life. Further studies are also required to investigate whether such profiles and OIs translate into meaningful bone health metrics. Moreover, although OI offers an advantage over previous research as it focusses on the mechanical load rather than metabolic load, more research investigating the dose–response relationship between OI and bone health in youth are needed. Finally, longitudinal studies in children and adolescents investigating whether using OIs provides additive information beyond moderate-to-vigorous PA and vigorous PA for the development of bone health and in identifying children and adolescents with increased risk of suboptimal bone development are warranted.

CRediT authorship contribution statement

Eero Haapala conceptualised the work and drafted the first version of the work; Timo Jaakkola, Arto Gråsten, and Mikko Huhtiniemi collected the data and contributed and revised the intellectual content of the work; Timo Rantalainen made the numerical analysis with accelerometer data and contributed and revised the intellectual content of the work; Arto Gråsten performed the main statistical analysis and contributed and revised the intellectual content of the work; Francisco Ortega conceptualised the work and contributed and revised the intellectual content of the work; Timo Jaakkola will act as guarantor for the paper; all authors read and approved the final version of the manuscript.

Declaration of the role of study sponsors and sole submission

All authors have significantly contributed to the work, all authors have approved the manuscript, and there are no conflicts of interest.

Consent to participate

The parents or caregivers of the children gave their written informed consent, and the children gave their verbal assent to participation.

Funding information

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Confirmation of ethical compliance

The Human Sciences Ethics Committee of the University of Jyväskylä approved the study protocol.

Data availability

The data that support the findings of this study are the property of the University of Jyväskylä and therefore available from the principal investigator, [TJ], upon reasonable request.

Declaration of interest statement

The authors have no relevant financial or non-financial interests to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsams.2024.02.005.

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