Effects of BMI on Bone Loading due to Physical Activity

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Abstract

The aim of the current study was to compare bone loading due to physical activity between lean and, overweight and obese individuals. Fifteen participants (lower BMI group: BMI < 25 kg/m^2, n=7; higher BMI group: 25 kg/m^2 < BMI < 36.35 kg/m^2, n=8) wore a tri-axial accelerometer on one day to collect data for the calculation of bone loading. The International Physical Activity Questionnaire (short form) was used to measure time spent at different physical activity levels. Daily step counts were measured using a pedometer. Differences between groups were compared using independent t-tests. Accelerometer data revealed greater loading dose at the hip in lower BMI participants at a frequency band of 0.1–2 Hz (P = .039, Cohen's d = 1.27) and 2–4 Hz (P = .044, d = 1.24). Lower BMI participants also had a significantly greater step count (P = .023, d = 1.55). This corroborated with loading intensity ($d \geq 0.93$) and questionnaire (d = 0.79) effect sizes to indicate higher BMI participants tended to spend more time in very light, and less time in light and moderate activity. Overall participants with a lower BMI exhibited greater bone loading due to physical activity; participants with a higher BMI may benefit from more light and moderate level activity to maintain bone health.

Keywords: pedometer, accelerometry, loading intensity, loading frequency

Word count: 4757 words

Introduction

The prevalence of overweight and obesity is increasing, with the World Health Organisation reporting that over 1.9 billion adults worldwide were overweight in 2014, of which over 600 million were obese.[1] Although reasons for the development of being overweight or obese are multifactorial,[2] a decrease in physical activity has been shown to have an inverse relationship with body mass.[3,4] Furthermore, obese people who undertake more physical activity have been shown to be metabolically healthier than their less active counterparts.[5,6]

It is still unclear as to the effects of being overweight or obese on bone health. A high body mass has been associated with increases in bone mineral density due to the load on weight-bearing bones,[7] and the increased secretion of bone active hormones.[8] Although this implies obesity has a positive effect on bone health, more recently it has been suggested that obese people have poor bone quality and increased fracture risk.[9-11] This may be due to factors such as the excess weight due to adiposity and the changes this induces at a cellular level.[9,11] Also, when the mechanical loading effects of total body weight on bone mass are adjusted for, an inverse relationship between bone mass and fat mass has been reported.[12]

Physical activity can counteract some of the negative effects of adiposity on bone health and it is generally accepted that certain types of exercise strengthen bone.[13,14] Exercises that are particularly osteogenic are weight-bearing intermittent dynamic activities which are high impact, applied at a high strain rate, and are unusual or diverse.[15] Mechanical loading has been shown to alter cellular mechanics to favour osteoblastogenesis, and at the expense of adipogenesis.[16] Bone benefits from mechanical loading via dynamic loads through physical activity[17] rather than static loads due to excess adiposity alone, indicating there is no mechanical advantage to the bone as a result of obesity unless accompanied by a greater lean mass and a physically active lifestyle.[9] It is therefore important that the contribution of physical activity to factors associated with bone remodelling and adaptation in overweight and obese people are better understood.

Factors that determine bone adaptation to mechanical loading include loading magnitude, loading frequency (rate), and duration of loading.[14] Various methods have been used to quantitatively assess these factors in physical activity, including questionnaires, pedometers, and accelerometers. Among these methods, self-report questionnaires and pedometers are convenient ones to use. Both methods have been employed in studies reporting positive associations between physical activity and various measures of bone health.[18-21] Questionnaires rely on the participants' subjective interpretation of participation in physical activity and have been shown to correlate weakly with objective measures such as pedometers and accelerometers.[22,23] However, although pedometers are regarded as an objective measurement device the data obtained does not offer the same level of detail as accelerometers. Specifically, they are not able to give precise information about the characteristics of the activity (e.g. loading magnitude or loading frequency) in relation to bone adaptation. Generally, pedometers have been regarded as less accurate than accelerometers in physical activity assessment[24,25] and are affected by increasing BMI and waist circumference, and greater pedometer tilt in overweight and obese adults leading to an underestimation of actual steps.[25]

Accelerometers offer researchers the opportunity to gather more precise information about the characteristics of the physical activity which are specifically associated with bone adaptation. To quantify the specific elements of physical activity that have an osteogenic effect, Turner & Robling[14], developed the osteogenic index which incorporates the important factors identified as leading to bone formation (loading magnitude, loading frequency and duration of loading). Accelerations recorded on accelerometers attached to participants correlate with the mechanical loading forces acting on the body during physical activity.

Therefore, it is possible to use acceleration data to assess the loading intensity (magnitude of loading x loading frequency[14]) of physical activity on the underlying skeleton, at the site which the accelerometer is attached to. Previous research has shown that loading intensity can be calculated using a combination of the magnitude and frequency of the acceleration signals.[26,27] From these data the duration of activities at each intensity level can be derived thus quantifying bone loading with respect to the three elements identified by Turner & Robling,[14] as important to osteogenesis. The primary aim of the present study was to compare bone loading estimates due to physical activity in lean (participants with a lower BMI) and overweight and obese individuals (participants with a higher BMI) using our accelerometry based method to quantify the loading intensity and overall loading dose at the hip. Secondary aims were to compare physical activity levels between the two groups using questionnaire and pedometer data. The following hypotheses were tested: 1) There is an association between mechanical loading during daily physical activity and BMI (lower BMI versus higher BMI) when assessed by accelerometry based methods; 2) There is an association between physical activity levels and BMI (lower BMI versus higher BMI) as assessed by questionnaire and pedometer.

Methods

Fifteen participants volunteered to take part in the study and were divided into lower BMI (BMI < 25 kg/m^2) and higher BMI (BMI > 25 kg/m^2) groups (Table 1). The higher BMI group comprised both overweight ($n = 6$) and obese ($n = 2$) participants. All participants gave written informed consent prior to participating in the study, which had been approved by the Institutional Ethics committee (Ref: LSC 11/010). The volunteers were a subset of those taking part in an investigation into the mechanisms that may link body mass index with breakfast consumption.[28]

Table 1 about here

The protocol required that a tri-axial accelerometer (MSR 145B, MSR Electronics GmbH, Henggart, Switzerland) was attached to the skin on the right side of the pelvis directly above the hip joint centre (Figure 1), using double-sided wig tape applied to the rear of the sensor and further secured with Finepore tape over the top of the sensor. In agreement with the participant the accelerometer was pre-set to record data (10 Hz) for one specified day between 9 am – 9 pm. This required the participant to attach the accelerometer themselves on the morning of the data collection, and therefore detailed instructions and demonstrations on how and where to attach the accelerometer were provided in advance. Twelve hours of data collection was chosen due to limitations in the amount of data the accelerometer could store when recorded at 10 Hz. The specified time period was chosen as this represented the portion of the entire day when participants would be going about their daily routines. Whilst wearing both the pedometer and accelerometer participants were instructed to follow their normal routines. As the accelerometer was worn for one day only, a day that reflected a typical day's activity was chosen. This was agreed with the participant beforehand and days likely to result in less or more than normal activity were avoided. Typical physical activity levels of participants were measured using the short form of the International Physical Activity Questionnaire (IPAQ-SF), which has been previously reported as a valid and reliable measure of physical activity.[29] It was completed by participants at the start of the study. Additional daily physical activity data were collected using a pedometer (Yamax Digiwalker SW-200, Tokyo, Japan). Participants were instructed to wear the pedometer either on the waist band, if available, or on the front pocket of their clothing. They attached the pedometer as they arose in the morning and only removed it when going to bed, with the exception of bathing. The number of steps per day was recorded by the participant for a period of two distinct weeks. These weeks coincided with participation in the larger study where participants were assigned to one week of following a breakfast eating protocol and one week of skipping breakfast.[28]

Figure 1 about here

Prior to processing the acceleration data it was screened to ensure 12 hours of wear time was indicated in the signal. The details of the method for analysing acceleration data can be found in our previous publications.[26,27] A short introduction of this method is provided below. The 12 hours of accelerometer data were exported to a personal computer and processed using a custom written computer programme in MATLAB (Version R2014a, MathWorks Inc., Natick, MA). The resultant acceleration was calculated from the data and filtered using a Butterworth band pass filter (0.1-5 Hz) to remove static gravitational acceleration and noise.[27] The resultant acceleration was divided into 5 s segments. A Fast Fourier transformation was applied to each 5 s segment to obtain the Fourier series of the acceleration signal in the frequency domain. Loading intensity in body weights per second (BW/s) was then calculated for each 5 s segment from its Fourier series by summing the product of acceleration magnitude and frequency across 0.1 to 5 Hz:

$$LI = \sum_{f_i=0.1}^{5\,Hz} \frac{(A_i \times f_i)}{g} \tag{1}$$

where LI is the loading intensity (BW/s), f_i is the ith frequency in the Fourier series (Hz), only terms with frequency between 0.1 and 5 Hz were used, A_i is the acceleration (m/s^2) at frequency f_i. and g is the gravitational acceleration (9.81 m/s^2).

Then the time (s) spent on activity with loading intensities (calculated for the 0.1-5 Hz frequency band) of < 5 BW/s (very light), > 5 BW/s (light), > 10 BW/s (moderate), > 15 BW/s and > 20 BW/s (vigorous) was calculated by multiplying the number of segments within each intensity category by the duration of each segment (5 s).

Overall loading dose (BW) was calculated by summing the product of loading intensity and duration (i.e. 5 s) at each segment across the 12 hour recording period:

$$LD = \sum_{k} 5 \times LI \tag{2}$$

while *LD* is the loading dose, *LI* is the loading intensity, and k is the number of segments in the twelve hour recording period.

Loading dose was also calculated at frequency bands 0.1-2, 2-4, and 4-5 Hz separately by the following methods. First, loading intensity at each frequency band was calculated as (for example, at 0.1-2 Hz band):

$$LI\_B = \sum_{f_i=0.1}^{2\,Hz} \frac{(A_i \times f_i)}{g} \tag{3}$$

where LI_B is the loading intensity at a frequency band (e.g. 0.1-2Hz in this case) (BW/s), f_i is the ith frequency in the Fourier series (Hz), A_i is the acceleration (m/s^2) at frequency f_i. and g is the gravitational acceleration (9.81 m/s^2).

Then loading dose at a frequency band (BW) was calculated by summing the product of loading intensity in that frequency band and duration (i.e. 5 s) at each segment across the 12 hour recording period:

$$LD\_B = \sum_{k} 5 \times LI\_B \tag{4}$$

where *LD_B* is the loading dose at a specific frequency band (e.g. 0.1-2, 2-4, or 4-5 Hz), and *k* is the number of segments in the twelve hour recording period.[26]

The resulting data from the above calculations represented the total amount of bone loading and bone loading at different frequency bands over the twelve hour period. Although it is not possible to distinguish the exact activity undertaken in each of the frequency bands calculated, association of the frequency bands with common activities is such that the faster moving activities contain greater high frequency components. For example a greater amount of the loading intensity due to fast running is above 4 Hz when compared to slow walking.[27]

IPAQ-SF Data: Questionnaires were analysed in accordance with guidelines produced by the IPAQ Research Committee.[30] Physical activity of the previous week relating to leisure, domestic, work, and transport activities was assessed and reported as separate scores for walking, and moderate and vigorous intensity activities as well as total activity. Data for each category were expressed as metabolic equivalent minutes per week (MET-min/week). Time spent sitting was also evaluated and reported as minutes/day. One participant's data from each group was excluded due to partial completion of the IPAQ-SF questions.

Pedometer Data: The mean daily pedometer scores for each of the two weeks of data collection were calculated and a dependent t-test was conducted, which ascertained that there was no statistically significant difference between the breakfast eating and skipping weeks ($t(13) = 0.515$, $P = .615$), which has also been reported in a previous study.[31] Therefore the pedometer data collected were pooled and an average daily step count over a two week period was obtained.[32] The mean daily step count for the day on which the accelerometer was worn was also calculated for each group. Step data were not available for one member of the lower BMI group.

The data was analysed statistically. Variables were tested for equality of variance using Levene's test. Independent t-tests were used to assess differences between lower BMI and higher BMI groups. The level of significance for a two-tailed test was set at $P < .05$. Cohen's d (*d*) effect size was calculated as the difference between means divided by the pooled standard deviation and reported as 0.2 - 0.49 small, 0.5 - 0.79 medium, ≥ 0.8 large.[33] Statistical analysis was carried out using SPSS (IBM SPSS Statistics Version 20; IBM Corp, NY, USA) and Excel (Microsoft, Redman, WA, USA).

Results

A significantly greater mechanical loading dose, and large effect size, was observed for lower BMI participants at frequency bands of 0.1-2 Hz and 2-4 Hz (Table 2). This indicates that loading dose was higher in lower BMI participants in both low and high frequency ranges. For duration of activity at differing loading intensities there were no significant differences. However, large effect sizes were observed for the duration of activity with loading intensities < 5 BW/s to > 10 BW/s. Whilst not significant Table 2 shows lower BMI participants undertaking low intensity (< 5 BW/s) activities for less time and higher intensity activities (> 5 and > 10 BW/s) for more time.

Table 2 about here

Analysis of steps taken indicated there was a significant difference and large effect size between lower BMI and higher BMI groups in the number of steps taken on the day the accelerometer was worn, with lower BMI participants recording significantly more steps. When comparing mean daily step count averaged from a two week period there was no significant difference between the groups (Table 3).

The IPAQ-SF questionnaire revealed no significant difference in time spent on moderate physical activity between groups. Nevertheless there was a large effect size (*d* =

0.79), with the data indicating lower BMI participants reported spending more time undertaking a moderate level of activity than those who were in the higher BMI group (Table 3). No significant differences and only low to moderate effects were noted for measures of vigorous and walking activity, and sitting time between groups.

Table 3 about here

Discussion

The primary aim of this study was to compare bone loading estimates between lean (lower BMI group) and overweight and obese individuals (higher BMI group), assessed by accelerometry. The key findings were that the lower BMI participants experienced a greater loading dose at frequencies up to 4 Hz. This indicates a greater amount of total bone loading normalised to body weight during the twelve hour period that the participants were recorded, at loading frequencies in the 0.1-2 Hz and 2-4 Hz frequency bands.

Accelerations of the upper body generated during daily activities ranging from slow walking, to fast running and stair climbing have been shown to contain frequencies within the above range of 0.1 to 4 Hz. These activities also contain some higher frequency components above 4 Hz.[27,34] As the intensity of activity increases, for example by increasing the speed at which it is performed, the portion of higher frequency components contained in the signal increases. This indicates that light and moderate physical activity has frequencies mainly in the lower frequency range and as the physical activity becomes more vigorous greater increases in the higher frequency components are observed.[27] The results of this study therefore indicate that lower BMI participants exhibit a higher loading dose in light and moderate physical activity but not in vigorous activity.

Low velocity, low impact activities have been shown to beneficially modify bone geometry[35], which is achievable through light and moderate physical activity. In addition increased loading frequency has been associated with increased bone formation[36], therefore our results suggest mechanical loading induced due to physical activity may be compromised in the higher BMI group at both low and high frequency ranges, limiting the osteogenic effects of their physical activity. At the higher (4-5 Hz) loading frequencies differences were not significant although the effect size was still quite large, suggesting the trend may continue. It is also possible participants engaged in activities with a mechanical loading frequency above 5 Hz. The loading dose of physical activity that generated frequencies above 5 Hz were not analysed in the current study due to filtering the acceleration signal with a cut-off frequency of 5 Hz. This was to reduce errors contained in the measurement of the acceleration signal as a result of high frequency signals that were contaminated by skin movement, rather than the true signal generated by the physical activity undertaken.

With respect to the intensity of the physical activity, only moderate and vigorous activity levels and high impacts have been shown to improve bone density in adolescents and middle aged women.[26,37,38] Previous work by Kelley et al.[27], has demonstrated that types of activities generating very light (< 5 BW/s), light (> 5 BW/s), moderate (> 10 BW/s) and vigorous (> 15 BW/s) loading intensities include slow walking, fast walking, slow running and, normal and fast running respectively, for acceleration data recorded at the lumbar spine. In the current study the measure of duration of physical activity at specific loading intensities allowed the amount of time engaged in activities with the potential of improving bone density at the site of the hip to be quantified.

Although not significant the effect sizes noted in the current study suggests higher BMI participants may spend more time engaging in low intensity (very light) exercise < 5 BW/s, whilst the lower BMI participants engaged in more activity at intensities greater than 5 or 10 BW/s (light and moderate activity) (Table 2). This supports the results on loading dose where participants with a lower BMI had a higher dose at both 0.1-2 Hz and 2-4 Hz. It further highlights that a greater portion of the physical activity the lower BMI participants engaged in at these doses were of the intensity of normal walking or greater. Whereas the higher BMI group had a greater portion of their low intensity physical activity spent in slow walking or similar. If higher BMI participants are generally lacking in moderate activity, this could explain the poor bone quality and increased fracture risk previously reported.[9-11] It is recommended further research is undertaken to corroborate this evidence.

At higher intensities (> 15 and > 20 BW/s) the differences in duration of loading intensity were not significant, nor were the effect sizes noteworthy (Table 2). High intensity physical activity is likely to contain a greater proportion of high frequency components.[27] Therefore, this again supports our results on loading dose where no significant differences were found between the groups for physical activity at frequencies of 4-5 Hz.

Overall, the significantly greater loading dose found in the lower BMI group, supported by the findings for loading intensity, provide an insight into the characteristics of their physical activity which are positively related to osteogenesis. Loading dose was calculated by multiplying the loading intensity by time duration. Therefore the significant differences in loading dose mean that the physical activity of the lower BMI group must have one or all of the following characteristics: 1) their loading magnitude during physical activity was larger, 2) their physical activity loading frequency was larger, or 3) they spent more time on light or moderate physical activity than the higher BMI group. These changes correspond with the factors identified by Turner & Robling that determine bone adaptation, namely increased loading magnitude, loading frequency (rate), and duration of loading.[14]

The mean total time spent by either group in activities > 15 BW/s was no more than 10 minutes in the twelve hour period, demonstrating that neither group engaged in much vigorous activity. This correlates with previous research that suggested engaging in activities with a high acceleration response are rare.[39] However, it has been shown that the mechanosensitivity of bone declines after 20 loading cycles and bone formation improves with rest periods between loading cycles.[14,40,41] Therefore, as the short periods of vigorous physical activity engaged in by both groups reaches the intensity levels associated with increases in bone mineral density,[26,37,38] further research into whether this small amount of vigorous physical activity is sufficient to maintain and enhance bone health is warranted. In addition examining the nature of the activities undertaken during vigorous physical activity would inform such exercise interventions.

Acceleration signals attenuate as they travel through the body[42] therefore to confirm whether the physical activity undertaken produces the required loading at the site of interest the accelerometer should be placed near that site. Jämsä et al.,[37] indicated an association between physical activity and proximal femur bone mineral density, dependent on acceleration levels generated at this site via an accelerometer worn near the iliac crest. In the current study the data indicates the osteogenic potential of activities in relation to the hip in lower BMI and higher BMI participants, rather than generalised links between physical activity and its contribution to bone health.

Secondary aims of the study were to compare physical activity levels between the two groups using questionnaire and pedometer data. The results from the IPAQ-SF and pedometers showed that the only significant difference between lower BMI and higher BMI groups was a greater mean daily step count, on the day the accelerometer was worn, in lower BMI participants. Whilst this significant result would suggest that the lower BMI participants experience a greater amount of bone loading the accelerometer data for lower BMI participants revealed that just over half an hour of activity within the twelve hour recording period was of a moderate intensity or greater, the level associated with increases in bone mineral density.[26,37,38] Therefore, caution should be applied when using a pedometer to quantify physical activity levels in studies investigating bone health. This could further explain why previous research has failed to find an association between pedometer data and instruments designed to measure bone specific physical activity,[32] or bone strength.[43]

Although the day chosen to wear the accelerometer was to be reflective of typical activity (i.e. avoid a day of particularly high or low activity with respect to the rest of the week) the results indicate the number of steps performed on the day the accelerometer was worn for the lower BMI group were higher than the average daily count for a two week period (Table 3). Further investigation of the daily step data indicated that the step count for the day the accelerometer was worn was between the maximum and minimum daily step counts over a two week period for all except one lower BMI and one higher BMI participant. For both of those participants the step count on the day the accelerometer was worn represented their maximum daily score. As daily activity is likely to vary across a week it would appear that our data is representative of a typical day in the majority of participants when sampling for one day only.

It appears that the significant difference observed in steps taken between groups on the day the accelerometer was worn is potentially due to a combination of the following factors. The step count range on that day was smaller for the lower BMI (10650 to 14828 steps) compared to higher BMI (3562 to 14562 steps) participants. Also when compared to the range of steps/day recorded over the 2 week period for each group (lower BMI: 1225 to 17252; higher BMI: 1813 to 25746), the data was in the upper end of the range for the lower BMI group and lower end of the range for the higher BMI group. Exploration of the daily step counts over the two week period supports this. Therefore, it is possible that having been instructed to wear the accelerometer on days representative of their typical daily physical activity the lower BMI group tended to avoid days of low activity as they were not the norm and vice versa for the higher BMI group.

The IPAQ-SF data did not reveal any significant differences in physical activity levels between groups. However the effect size (d = 0.79) suggested greater engagement in moderate physical activity by lower BMI participants which corroborates the accelerometer data (d = 0.93 for time of intensity > 10 BW/s). As previous studies have also found physical activity measured from questionnaire data to be positively associated with measures of bone health,[19-21] it is possible that physical activity questionnaires may be a more effective, quick and easy way to assess measures of physical activity in studies relating to bone health than a pedometer. However, as many physical activity questionnaires, including the IPAQ-SF, define physical activity through energy expenditure calculated in METs,[21,30] they do not distinguish between weight-bearing and non-weight bearing exercise and thus underestimate the loading of physical activity on the skeletal system.[21] Additionally, there are limitations to relying on recall to estimate physical activity level through questionnaires and the IPAQ-SF has been shown to overestimate physical activity.[22]

It is acknowledged that there are some limitations to the present study that must be taken into account when interpreting the data. The sample size for this study is small and the variability in the physical activity data collected by all three methods can be considered high. Therefore we acknowledge that interpretation of the p-values and effect sizes must be considered with caution. However, albeit a small sample novel data is presented in relation to the primary aim which gives us a first estimate of what the effect sizes are in relation to the hypothesis tested. Future studies should consider grouping lower BMI and higher BMI participants into sedentary and active categories to investigate the interaction of BMI and physical activity levels. Where possible data for multiple days should be recorded to get a fuller picture of physical activity during typical daily routines, to differentiate between week days and weekends a seven day collection period has been suggested.[44] This is illustrated in the current pedometer datasets where two of the higher BMI participants displayed the pattern of engaging in a very large number of steps one day/week during the two week pedometer data collection period. However to ensure the statistical analysis of the pedometer data in the current study was not influenced by outliers Grubbs Test[45] was performed; as no outliers were detected all pedometer data was included in the subsequent analysis. In line with the current data collection and processing protocols it is possible participants engaged in activities with a mechanical loading frequency above 5 Hz which would have been removed by the filtering process adhering to Nyquist's theorem. Also there is the possibility of skin movement artefact and additional adipose tissue affecting the accelerometer signal. However the influence of soft tissue on the measurement of bone acceleration was minimised in this study by filtering acceleration data at the cut-off frequency of 5 Hz, as a previous study found that bone accelerations can be reliably measured using skin mounted accelerometers for frequency up to around 5 Hz.[42]

In summary, magnitude, frequency and duration of mechanical loading are important parameters to determine bone formation and maintenance. This study is the first to quantitatively assess mechanical loading at the hip in overweight and obese (higher BMI) participants using these parameters based on acceleration signals during free-living. This enables us to reveal the key nature of physical activity that is related to bone health in higher BMI participants. Lower BMI participants engaged in physical activity that elicited a greater mechanical loading dose to the hip than did higher BMI participants, and had a greater step count. The use of accelerometry to estimate external mechanical loading proved an effective means of providing details of the characteristics of physical activity associated with osteogenesis beyond what the pedometer data provided. The osteogenic potential of mechanical loading dose in the higher BMI group was compromised at a range of frequencies. Analysis of the loading dose and intensity data indicated the higher BMI participants took part in less light and moderate physical activity and therefore have less potential for positive benefits to bone geometry or density. Thus higher BMI participants may benefit from more light and moderate level physical activity to maintain bone health. Intensity of physical activity data revealed that just over half an hour of total activity within the twelve hour recording period was of a level associated with increasing bone density (moderate and vigorous physical activity) for both groups. Indicating pedometer data alone should not be relied on when studying the effects of exercise on bone health.

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Table 1 Participant demographics (mean ± SD).

Group	n	Sex	Age (y)	Height (m)	Body Mass (kg)	BMI (kg·m^{-2})
Lower BMI	7	4 female	34.6 ± 7.2	1.73 ± 0.10	67.1 ± 5.8	22.5 ± 1.3
Higher BMI	8	6 female	26.6 ± 6.0	1.71 ± 0.11	85.1 ± 15.7	28.9 ± 3.4

BMI = body mass index

Table 2 Accelerometer physical activity data for lower BMI and higher BMI groups.

Variable	Mean ± SD		*t*	*df*	*P*	*d*
	Lower BMI	Higher BMI				
Overall Loading Dose (BW) 0.1-5 Hz	90890 ± 16175	71063 ± 20714	2.043	13	.062	1.14
0.1-2 Hz Loading Dose (BW)*	16474 ± 3615	12222 ± 3563	2.290	13	.039	1.27
2-4 Hz Loading Dose (BW)*	48203 ± 8429	37008 ± 10714	2.224	13	.044	1.24
4-5 Hz Loading Dose (BW)	27429 ± 5068	22658 ± 6925	1.502	13	.157	0.83
Duration of Loading Intensity < 5 BW/s (s)	37922 ± 1514	39507 ± 1876	1.782	13	.098	-0.99
Duration of Loading Intensity > 5 BW/s (s)	5278 ± 1514	3693 ± 1876	1.782	13	.098	0.99
Duration of Loading Intensity > 10 BW/s (s)	2092 ± 1475	1001 ± 1042	1.672	13	.118	0.93
Duration of Loading Intensity > 15 BW/s (s)	307 ± 288	440 ± 594	-0.560	10.384	.587	-0.30
Duration of Loading Intensity > 20 BW/s (s)	170 ± 297	226 ± 375	-0.321	13	.753	-0.18

* Statistically significant difference; *d* = effect size

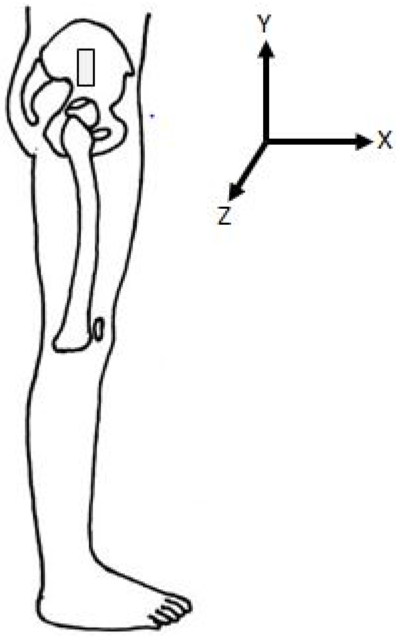
Table 3 International Physical Activity Questionnaire short form (IPAQ-SF) and pedometer physical activity data for lower BMI and Higher BMI groups.

Variable	Mean ± SD		*t*	*df*	*P*	*d*
	Lower BMI	Higher BMI				
IPAQ-SF Data						
Walking (MET-min/week)	1524 ± 1577	966 ± 1177	0.729	11	.481	0.44
Moderate Physical Activity (MET-min/week)	593 ± 478	291 ± 338	1.330	11	.210	0.79
Vigorous Physical Activity (MET-min/week)	1013 ± 513	1406 ± 1273	-0.748	8.135	.476	-0.42
Total Physical Activity (MET-min/week)	3130 ± 1696	2664 ± 1329	0.557	11	.589	0.33
Time Sitting (min/day)	470 ± 219	377 ± 83	1.043	11	.319	0.62
Pedometer Data						
Mean Daily Step Count	9386 ± 982	8272 ± 2910	1.009	8.996	.340	0.53
Step Count (on day accelerometer was worn)*	12575 ± 1798	8175 ± 3797	2.608	12	.023	1.55

* Statistically significant difference; *d* = effect size

Figure Captions

Figure 1 – Location and co-ordinate system of the accelerometer.


Y
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