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Technical Note

Comparison of Physical Activity Measured by Self-Reported Physical Activity and Wearable Device Xiaomi MI2 Band in Preadolescent School Children – A Pilot Cross-Sectional Study

AYSHA ALMAS‡1, SHIRAZ HASHMI‡2, ADIL ELAHI†3, OM PARKASH‡1, SANIA SABIR†1, and ROMAINA IQBAL‡4

[1]Department of Medicine, Aga Khan University, Karachi, PAKISTAN; [2]Department of Surgery, Aga Khan University, Karachi, PAKISTAN; [3]Research Fellow, Aga Khan University, Karachi, PAKISTAN; [4]Department of Community Health Sciences, Aga Khan University, Karachi, PAKISTAN

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 17(7): 565-575, 2024. The purpose of this study is to compare physical activity measured by the wearable device Xiaomi Mi2 Band and self-reported physical activity by YPAQ in preadolescent school children. A pilot cross-sectional study was performed on a subsample (5%=n=60) of preadolescent children within a parallel-group feasibility intervention trial (n=1000). All children aged 9-11 years enrolled in the schools were included in the study and children with any physical disability were excluded. Self-reported physical activity was recorded through the modified version of the Youth Physical Activity Questionnaire (YPAQ) and automatic physical activity was measured by the Xiaomi Mi2 band over 7 days. Data from the Xiaomi Mi2 band was synchronized with its mobile application from where data was transferred to an excel sheet. Data on 7-day total physical activity in minutes and 7-day total step count were recorded by the Xiaomi Mi2 band. Student's t-tests were used to determine whether significant differences were present between self-reported physical activity and by Xiaomi Mi2 band. A Bland-Altman method was also used to assess the degree of agreement between the two methods of measuring physical activity. Mean ± SD age of the children was 9.6 (± 1.0) years and 31 (51.7 %) were boys. The mean ± SD time spent in physical activity reported by YPAQ was 457.5 (± 136) minutes and by the Xiaomi Mi2 band was 594.7 (± 183) minutes. The Bland-Altman plot identified a mean bias between the methods (YPAQ and Xiaomi Mi2 band) of -157.6 (95% CI: 296.3, -611.0) minutes of 7-day physical activity. Physical activity measured by a wearable device, the Xiaomi Mi2 band can give overestimated values of physical activity compared to self-reported physical activity in preadolescent school children. However, when PA is measured through step counts by the Xiaomi Mi2 band converted to minutes, it is comparable to PA measured by YPAQ.

KEY WORDS: Adolescents, youth physical activity questionnaire, measurement, technology

INTRODUCTION

Physical inactivity has been termed the biggest public health problem of the 21st century (6). Regular physical activity can help children and adolescents to improve cardiorespiratory fitness, build strong bones and muscles, and reduce symptoms of anxiety and depression (10). It also reduces the risk of developing premature heart disease, cancer, type 2 diabetes, high blood pressure, osteoporosis, and obesity (12). Physical activity and higher levels of aerobic fitness in children have also been found to benefit brain structure, brain function, cognition, and school achievement (8). Lack of physical activity (PA) is a major factor contributing to the energy imbalance leading to overweight and obesity in children and adolescents that eventually attributes to the increased risk of chronic non-communicable diseases (NCD) in developing countries, particularly in South Asian region (19, 29). Evidence suggests that school-aged children and adults of South Asian origin are less active compared to the white British population (5). Measuring physical activity in children using a precise, valid, and reliable instrument is also important to quantify physical activity.

According to both the Center for Disease Control and the National Health Service, United Kingdom, children and adolescents aged, 6-17 years should do 60 minutes or more of moderate-to-vigorous physical activity (MVPA) each day, including daily aerobic activities 3 days each week (21, 25). Moderate-to-vigorous physical activity (MVPA) refers to activities equivalent in intensity to brisk walking or bicycling, or when the physical activity produces large increases in breathing and heart rate, such as jogging or aerobic dance (2). According to the World Health Organization (WHO) country factsheet, there are insufficient levels of physical activity in Pakistan as a whole (28). Jafar et al. reported that only 7% of girls and 30% of boys aged 13–14 years meet the recommended physical activity of 1 hour per day (14).

Traditionally, physical activity is mostly assessed using self-reported questionnaires including the youth physical activity questionnaire, except in controlled environments where an accelerometer is used to record physical activity data (34). A systematic review and meta-analysis revealed that self-reported measures underestimate sedentary time when compared to objective device measures and that there is a high degree of variability between and within tools used for self-reported measurement (26). Furthermore, the variable nature of physical activity over weeks and months makes daily activity difficult to assess using structured self-reported questionnaires (30). Accelerometers are commonly used in clinical and epidemiological research for more detailed measures of physical activity and to target the limitations of self-reported methods. Sensors are attached at the hip, wrist, and thigh, and the acceleration data are processed and calibrated in different ways to determine activity intensity, body position, and/or activity type (1). However, measuring physical activity through accelerometers is expensive and difficult to implement in non-clinical settings or over extended periods (24, 35). Additionally, accelerometers are cumbersome to be used by children and adolescents. A study showed that although the use of accelerometers is feasible in adolescents, there are many challenges to face in terms of recruitment, retention, and adherence to protocol with the use of accelerometers (3). Wearable wrist devices are becoming increasingly popular for monitoring physical activity. These devices are easy to use and are sufficiently priced to be used in large-scale studies. Wearable devices have been shown to have a high measurement accuracy for heart rate, number of steps, distance, and sleep duration (36). These variables can all be used as effective health evaluation indicators in large-scale studies or for personal use. The simplicity, relatively low cost, and ability to pick up short durations of activity (often missed by self-reported measures) make wearable devices popular tools for measuring PA (33). Furthermore, daily step count is readily accessible by which one can monitor and set physical activity goals (17).

It has already been shown that physical activity monitoring done through wearable devices can be used to make interventions in school children. One such study evaluated the feasibility and the effectiveness of PA intervention using wearable technology, framed with the real-time monitoring of children's PA and teacher-regulated strategies, and showed favorable results (7). Among wearable devices, Xiaomi Mi2 Bands are valid and dependable when measuring step counts, and thus, physical activity (22, 23, 35). Most studies on wearable devices have been done in high-income countries, and there is a paucity of data related to physical activity coming from low and middle-income countries (LMIC) like Pakistan (16).

As inadequate physical activity in adolescents is a cause of concern, it is important to use objective, easy-to-wear, and most importantly cost-effective measures to assess physical activity. Youth Physical Activity Questionnaire (YPAQ) is a reliable method of physical activity measurement; however, using wearable devices can serve as an objective method of measuring physical activity which can be less labor intensive and gives figures on measured physical activity that may be more accurate. Comparing both YPAQ and such wearable devices is necessary to design large school-based, feasible, culturally acceptable, and sustainable intervention strategies by intervening early in childhood to promote PA throughout a lifetime. Therefore, we conducted this study in a subsample of preadolescents in the School Health Education Program Pakistan to compare physical activity measured by the wearable device Xiaomi Mi2 Band and self-reported physical activity by YPAQ in preadolescent school children (1).

METHODS

Participants

The School Health Education Program in Pakistan (SHEPP) was a parallel-group feasibility intervention trial conducted in two schools from lower to middle-income areas at various locations in Karachi, Pakistan from 2017-2019. A pilot cross-sectional study was performed on a subsample (5%=n=60) of preadolescent children. This sample size was considered sufficient to conduct this pilot study. All children aged 9-11 years enrolled in the schools were included in the parent study and children with any physical disability were excluded. Random selection was done by class teachers to select four children from each class.

Protocol

All children were given a wearable device, Xiaomi Mi2 Band to wear for one week. Ethical approval was taken from the Ethical Review Committee (ERC), Aga Khan University (ERC number 2571-Med-ERC-13). Permission from school authorities was taken after which Informed consent from parents and assent was taken from children. We also declare that this research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (20).

Self-reported physical activity was recorded through the modified version of the Youth Physical Activity Questionnaire (YPAQ) which includes seventy-one diverse types of physical activity types (in school, out of school, moderate to vigorous physical activity, and sedentary time) which were assessed by time (minutes) spent in the type of physical activity. Xiaomi Mi2 band manufactured by Anhui Huami Information Technology Co., Limited, China, was used for measuring physical activity. Selected candidates were approached by research staff and explained verbally about smart watches, wearing instruction and their purpose. They explained the purpose of the study and the function of the Xiaomi Mi2 band. A unique ID # was placed on the back of the band for the next 7 days. After this, a fully charged Xiaomi Mi2 band was provided to the included children to wear for the next 7 days. They were instructed not to remove the device for 7 days and wear it throughout the week even during sleeping, bathing, and showering. After a week, research staff took the band from students and asked questions if removed or if any inconvenience occurred during the period. The Xiaomi Mi2 band data was synchronized by its application on a mobile device. Parents were provided with the contact number of research staff to be contacted in case of any issues related to the band. Data from YPAQ was also recorded at the time that the Xiaomi Mi2 band was collected back from the children.

Data from the Xiaomi Mi2 band was synchronized with its mobile application from where data was transferred to an Excel sheet. Data on 7-day total physical activity in minutes and 7-day total step count were recorded. In addition, we also converted step counts to minutes by using the Beighle`s formula (For girl's 7-day total step count / 93 and for boy's 7-day total step count / 91) (4). In addition, 7-day sleep time in minutes, 7-day sedentary time in minutes, 7-day physical activity distance traveled in miles and 7-day calories burnt in physical activity were also calculated. Data were then exported to the Statistical Package for Social Sciences (SPSS Version 26).

Statistical Analysis

Mean ± SD was used for quantitative variables and frequency and percentage for the qualitative variable. Pearson correlation is reported to see the correlation between self-reported physical activity and Xiaomi Mi2 band. Total physical activity, sedentary time, and sleep time were calculated by both YPAQ and Xiaomi Mi2 band. Student's t-tests were used to determine whether significant differences were present between self-reported physical activity and by Xiaomi Mi2 band. A Bland-Altman method was also used to assess the degree of agreement between the two methods of measuring physical activity (27).

RESULTS

Xiaomi Mi2 band was distributed among sixty-five preadolescent school children, out of which complete physical activity data were available for 7-days for 60 (92- %) children (5 were excluded; 2 for misplacement of the band, and 3 for incomplete data as they did not wear for consecutive 7-days). Mean ± SD age of the children was 9.6 (± 1.0) years and 31 (51.7 %) were boys. Mean ± SD height was 137 (± 9.1) cm, weight was 32.7 (± 9.6) Kg, and body mass index (BMI) was 17.0 (± 3.5) kg/m² Table 1 shows the demographics and physical activity pattern according to age groups, sex, and grade and compares the 7-day physical activity measured by YPAQ and the Xiaomi Mi2 band. The mean ± SD time spent in physical activity reported by YPAQ was 457.5 (± 136) minutes. The 7-day out of School physical activity in minutes by YPAQ was 376.3 (± 130) and in-school physical activity in a minute was 78.6 (± 17). The 7-day moderate to vigorous physical activity in minutes by YPAQ was 140.6 (± 74). The 7-day total physical activity in minutes by Xiaomi Mi2 band was 594.7 (± 183) and calories burnt in physical activity was 897.43 calories (± 309). However, when steps walked by the Xiaomi Mi2 band were converted to minutes, it was 452.8 (± 179.8) minutes which was closer to PA measured by YPAQ. A comparison of 7-day self-reported physical activity measured by the YPAQ and Xiaomi Mi2 band is shown in Table 2. The difference in 7-day physical activity was minimum between 7-day total physical activity in minutes by YPAQ and steps converted to minutes measured by Xiaomi Mi2 band; 15.8 (228) (p-value 0.6). The Pearson correlation was 0.1 (p = .7) between 7-day physical activity by self-reported (YPAQ in minutes) and Mifit Band (in minutes) or 7-day physical activity by Mifit Band (Steps converted to minutes).The mean ±SD 7 day self reported sleep time by YPAQ for boys is 3197 (493) and for girls is 3099 (481)(p=0.43) and 7 day self reported sedentary time is 6427 (484) for boys and 6536 (481)(p=0.38) for girls. The mean± SD 7-day sleep time measured by Xiaomi Mi2 band for boys is 3346 (325) and for girls is 3265 (393) (p=0.3) and sedentary time is 6022 (340) for boys and 6300 (370) for girls (p=0.004).

Table 1. Demographics and physical activity measured by Youth Physical Activity Questionnaire (YPAQ) and Xiaomi Mi2 band.

Demographics			7-day total physical activity in minutes YPAQ in minutes	Xiaomi Mi2 band *Actual in minutes*	Xiaomi Mi2 band *Steps converted to minutes*
		N (%)	Mean ± SD	Mean ± SD	Mean ± SD
Age Groups					
	9-10 years	28(46.7)	462 ± 139	556 ± 126	418 ± 121
	10.1-11 years	32(53.2)	452 ± 136	629 ± 220	484 ± 218
	*P value**		*p = 0.8*	*p = 0.2*	*p =0.2*
Sex					
	Boys	31(51.7)	459 ± 143	683(± 214	537
	Girls	29(48.3)	456 ± 132	506(± 81	368 ± 81
	*P value**		*p = 0.8*	*p = 0.001*	*p = 0.001*
Grade					
Four	Overall	30(50)	449 ± 146	610 ± 171	467 ± 165
	Boys	16(53.3)	445 ±164	692 ± 171	541 ± 169
	Girls	14(46.6)	454.4 ±125	487 ± 69	357 ± 74
Five	Overall	30(50)	464 ± 129	580 ± 0.6	439 ± 195
	Boys	14(46.6)	476 ±117	671 ± 272	531 ± 268
	Girls	16(53.3)	456.7 ±141	517 ± 88	357 ± 87
	*P value**		*p = 0.7*	*p = 0.9*	*p = 0.8*

**P value* is between age groups, sex, and overall grades

Table 2. Comparison of 7-day physical activity measured by Youth Physical Activity Questionnaire (YPAQ) and Xiaomi Mi2 band (*n*=60)

Variable	YPAQ in minutes	Xiaomi Mi2 band in minutes	Difference in minutes	*P value* **
	Mean ± SD	Mean ± SD	Mean ± SD	
7day total physical	457± 136	594 ± 183	157 ± 231	p <0.001
activity in minutes		452 ± 179.8 *	5 ± 228	p = 0.6
Age Groups				
9-10 years	462.9 ±139	556.4 ±126	93 ±186	
10.1-11 years	452 ±136	629 ± 220	176 ±274	P=0.26
7-day sleep time in minutes	3150 ± 486	3307 ± 359	157 ± 496	p = 0.01
Age Groups				
9-10 years	3300 ±520	3450 ± 330	150 ±521	
10.1-11 years	3018 ±419	3181 ± 339	163 ±481	
7-day sedentary time in minutes	6480 ± 481	6156 ± 379	323 ± 498	p <0.001
Age Groups				
9-10 years	6328 ±474	6043 ± 333	285 ± 499	
10.1-11 years	6612 ±455	6255 ±393	357 ± 503	0.58

*7-day total step count by Xiaomi Mi2 band =43879(15603),7-day Physical activity by Xiaomi Mi2 band (steps converted to minutes).
***P value* is of the difference between the Xiaomi Mi2 band and YPAQ using one sample t test.

The Bland-Altman plot (Figure 1) identified a mean bias between the methods (YPAQ and Xiaomi Mi2 band) of -157.6 (95% CI: 296.3, -611.0 minutes) minutes of 7-day physical activity. This bias between the two methods of measuring 7-day PA decreased to -15.8 (95% CI: 432, -464) minutes when steps measured by the Xiaomi Mi2 band were converted to minutes by using Beighle`s formula (Figure 2). The bias between the two methods in measuring sedentary activity was 323(95% CI: 1299, -653 minutes) Figure 3 reports the bias in measuring the time spent in sedentary activity in 7-days.

Post hoc sample size calculation: A minimum sample size of 200 participants will be required, assuming estimates of standard deviation of YPAQ (± 136 minutes) and Xiaomi Mi2 band (± 179 minutes), alpha level of 0.05 (95% confidence interval) and a difference in PA of 5 minutes between these two groups.

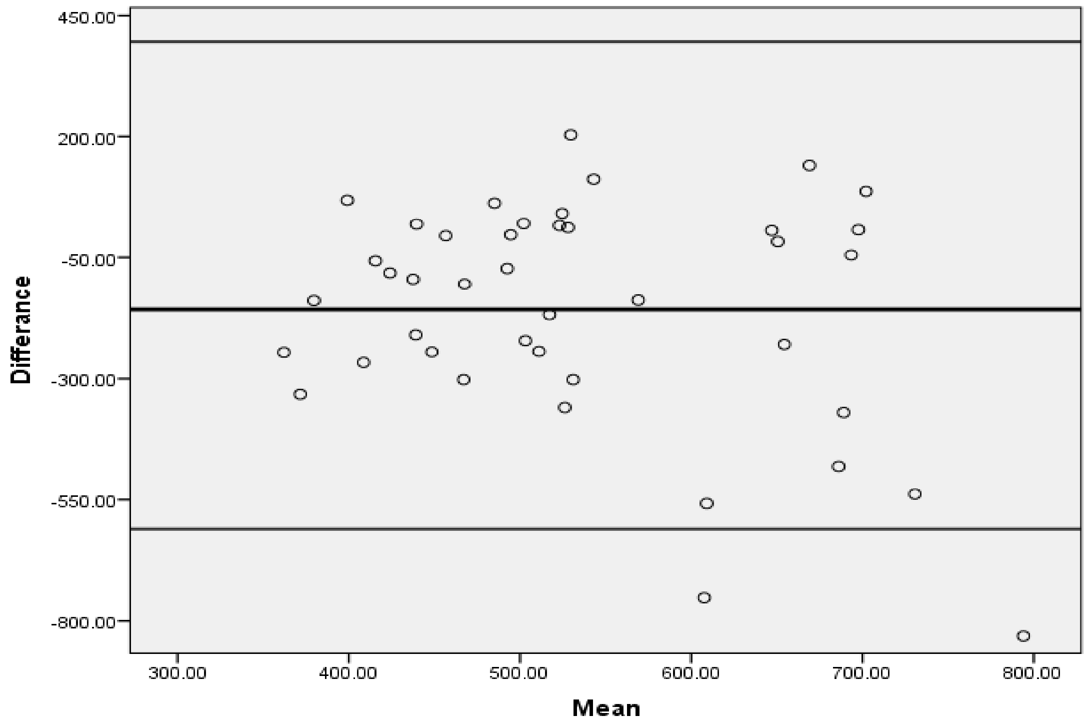

Figure 1. Bland Altman plots depict bias in measurements of 7-day Self-reported physical activity by Youth physical activity questionnaire and Xiaomi Mi2 band in minutes.

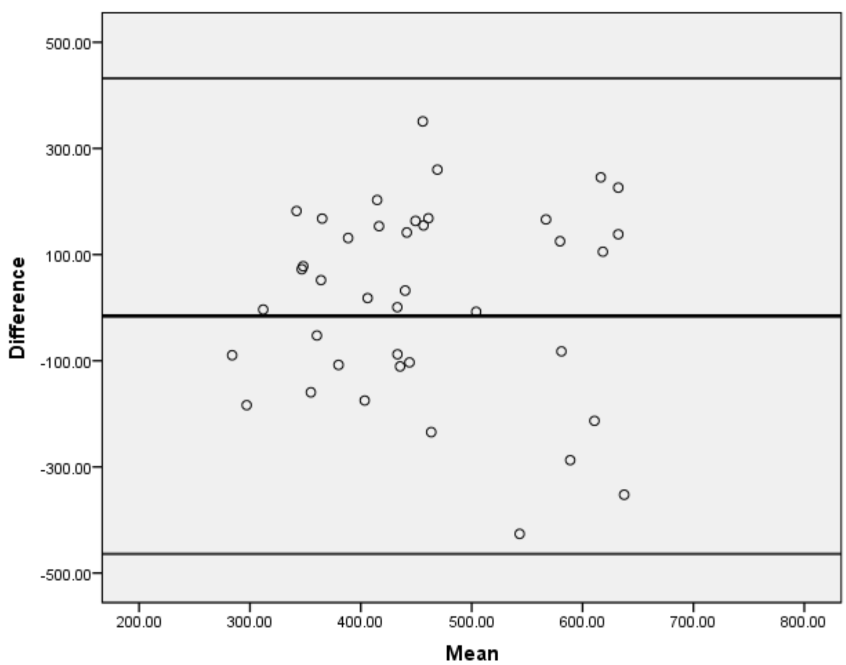

Figure 2. Bland Altman plots depict bias in measurements of 7-day Self-reported physical activity by Youth physical activity questionnaire and Xiaomi Mi2 band in minutes (Steps converted to minutes).

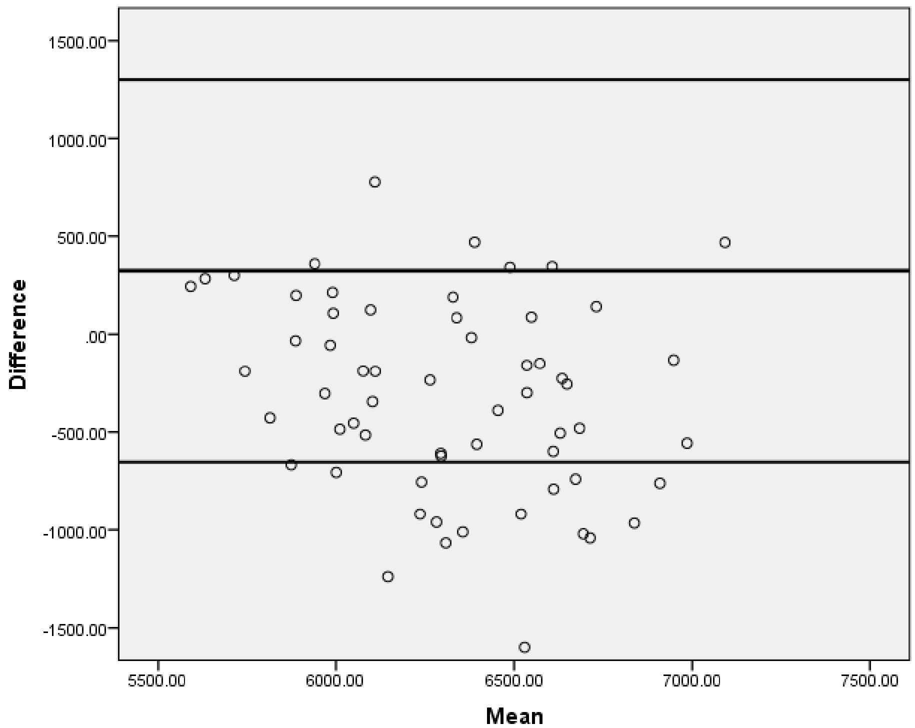

Figure 3. Bland Altman plots depict bias in measurements of 7-day Self-reported sedentary activity by Youth physical activity questionnaire and Xiaomi Mi2 band in minutes.

DISCUSSION

We compared the physical activity measured by YPAQ and Xiaomi Mi2 band in preadolescent children over 7-days. We found that minutes spent in physical activity by YPAQ are comparable when PA is measured through step counts by the Xiaomi Mi2 band converted to minutes using Beighle`s method (4).

Hao et al conducted a study aimed to determine the validity of eleven commercially available wrist-wearable activity devices including the Xiaomi Mi2 band for monitoring total steps and total 24-hour total energy expenditure (TEE) in nineteen healthy adolescents (11). They found that the predicted values by all wrist-wearable activity devices including the Xiaomi Mi2 band were strongly correlated with TEE obtained from the metabolic chamber. However, most of the wrist devices failed to show good validity when monitoring TEE but overestimated step counts by 963 to 2469 steps compared with the Accelerometer GT3X+. The Actigraph GT3X+ accelerometer is a reliable tool for measuring PA in adults under free-living conditions using normal data-reduction criteria. The Pearson correlation coefficient between Mi Band 2 Xiaomi and the triaxial accelerometer (GT3X+ [ACTi Graph]) for step counts was 0.42 moderate correlation (11). We report from this study that the physical activity time in minutes measured by the Xiaomi Mi2 band overestimates the time spent in physical activity when compared to PA measured by YPAQ. The explanation could be that it senses hand movements in a sedentary position as an activity. However, step counts by Xiaomi Mi2 band when converted to minutes using Beighle`s formula correlate better with the time spent with physical activity with YPAQ. Previous studies in adolescents have shown a moderate correlation between physical activity (not moderate to vigorous) measured by YPAQ and accelerometer, and that administering YPAQ is more practical (18). A systematic review of 57 articles about physical activity measurement by accelerometry and questionnaire has advised that studies use both questionnaires and accelerometers to gain the most complete physical activity information (32). We suggest that the Xiaomi Mi2 band can be more objective, practical, and cost-effective as an activity-measuring device compared to an accelerometer when used in conjunction with YPAQ. In a longitudinal prospective study of 586 adolescents from 12 to 15 years old enrolled in fourteen public schools, the overall sedentary time was 9 hours/day using the Adolescent Sedentary Activity Questionnaire (ASAQ) (31). Our study reports that the sedentary time in preadolescents, using both the YPAQ and Xiaomi Mi2 band was 15 hours/day which is much higher than what is reported in the former study. The reason for this could be reduced facilities for playing in school and out of school, even lower physical activity for girls due to cultural barriers, and lack of parental support for sports (13). The results of our study regarding sedentary behavior showed a slight deviation from YPAQ and accelerometer measurements, which is common due to differences in sex, socioeconomic status, and activities. YPAQ shows more minutes of sedentary behavior than an accelerometer. There is distinct leisure-time inactivity behavior among middle-income countries in comparison to other countries. Research suggests that the encouragement of individual wearable devices is the best way to overcome a sedentary lifestyle and achieve physical activity goals (15, 37).

The strength of the study is that it is one of the first ones to compare physical activity and sedentary behaviors in adolescents measured through YPAQ and Xiaomi Mi2 band from Pakistan. However, these findings are limited by the fact that the accelerometer which is the gold standard for measuring physical activity was not used in this study. This can be countered by the fact that studies have shown agreement between the measurement of accelerometers and the Xiaomi Mi2 band previously (11). We acknowledge that the correlation between YPAQ and Xiaomi Mi2 band is weak, however, there is an agreement between YPAQ, and steps (converted to minutes) measured by the Xiaomi Mi2 band. Evidence has debated correlation analysis and has preferred Bland-Altman analysis as a simple and accurate way to quantify the agreement between two instrument measurements (9). Additional limitations are that it is a single-centered study of a small sample size of school-going children, so results cannot be generalized to the general population. A large observational study on mixed population is warranted to validate our study findings.

Physical activity measured by a wearable device, the Xiaomi Mi2 band can give overestimated values of physical activity compared to self-reported physical activity in preadolescent school children. However, when PA is measured through step counts by the Xiaomi Mi2 band converted to minutes, it is comparable to PA measured by YPAQ. Also, Xiaomi Mi2 band could be a cost-effective wearable device in lower- and middle-income settings like Pakistan.

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