Original Article

Exploring the Relationship Between Daily Steps, Body Mass Index and Physical Self-esteem in Female Australian Adolescents

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Current research suggests that a decline in physical activity occurs some time during the adolescent years, but at what specific age this happens is unknown. To understand the Australian healthcare better it is important to determinate the age at which physical activity levels decline and the possible contributors to this phenomenon. The participants involved in the study were 13–15 year-old female adolescents ($n = 297$) from a high school in Southeast Queensland, Australia. The purpose of this study was to: (i) determine mean steps per day, using pedometers, for girls in grades 8–10, (ii) determine the body mass index (BMI) by measuring height (cm) and weight (kg), and (iii) using the Children and Youth Physical Self-Perception profile questionnaire, which identifies the determinants of physical self-worth in Australian female adolescents and their relationship to activity level and BMI. The study revealed that a significant drop-off in pedometer-determined mean daily steps occurred at grade 10, or approximately at 15 years of age. A significant inverse relationship between mean daily steps and BMI was found ($r = -0.251$, $p < 0.0001$). The study also revealed negative correlations between BMI and all self-perceptions ($p < 0.05$), except strength, which showed a positive correlation ($p < 0.05$). A positive correlation was also found between the level of physical activity and all self-perceptions, except global self-worth, which showed no significant difference.

Keywords: BMI, pedometers, physical activity, physical self-worth

Introduction

Childhood obesity is a major world health, social, and economic issue. It is known that children are becoming increasingly physically inactive (Jackson et al. 1999). In Australia, 25% of children aged 2–17 years are currently classified as overweight or obese (Australasian Society for the Study of Obesity 2004a,b). This is worrying because there are many well-documented health implications for individuals who are overweight or obese (Pate et al. 1995). Identification of sedentary children at risk of developing hypokinetic diseases is imperative to all stakeholders with an interest in children's health. At present there is no known data reporting on the physical activity levels, body mass index (BMI), physical self-esteem, and the relationship between these factors in Australian female adolescents in grades 8–10. Therefore, this research may be useful for targeting specific groups

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of students by promoting and implementing physical and psychologically appropriate education programs.

Pedometers (step counts)

To design appropriate physical education sessions, it is most important to determine the physical activity levels of adolescents first. Pedometers are increasingly being used to quantify habitual physical activity levels as they are noninvasive, practical, correlate with other physical activity measurements, and are accurate, reliable, and valid for measuring steps taken (Crouter et al. 2003; Schneider et al. 2003; Tudor-Locke & Myers 2001; Freedson & Miller 2000; Bassett et al. 1996). Despite giving an indication of habitual physical activity levels, pedometers are insensitive to many forms of physical activity and thus may not be a true indication of an individual's total physical activity levels. This must be taken into account when using pedometers to ascertain habitual physical activity levels, as a necessary participant compliance, because it is assumed that participants will comply fully with all the instructions and will not tamper with the pedometers.

Some research has shown decreasing physical activity levels with increasing chronological age, with the steepest decline occurring during the adolescent years (Thompson et al. 2003; Kimm et al. 2002; Trost 2001; Caspersen et al. 2000; Sallis 2000; Telama & Yang 2000; Van Mechelen et al. 2000), while other research shows consistent activity levels in grades 1–7 (Vincent et al. 2003). Research conducted using step counts (pedometers) reveals that a step count range of 7000–13,000 steps/day should be expected for healthy young adults (Tudor-Locke & Myers 2001). Further research carried out on primary school-aged girls from three countries (USA, Sweden, and Australia) indicates that mean step counts ranged from 11,221 to 12,322 steps/day for Australian girls (Vincent et al. 2003). There are, however, no current Australian data that have quantified female adolescents' habitual physical activity levels in grades 8–10 to determine the age at which the most significant decline in physical activity occurs.

BMI

When using the step counts as an indication of adolescents' physical activity levels it is also important to relate this to a health outcome, in this case, body composition. An appropriate body composition measure for the population studied is to calculate the BMI from height and weight measurements. BMI, which has been correlated with other body composition measures, is noninvasive and convenient for both screening and large fieldwork studies (Lynch et al. 2000; Dietz & Bellizzi 1999; Malina & Katmarzyk 1999). However, caution must be taken when using BMI with an adolescent population due to differences in the timing and tempo of sexual maturation (Lynch et al. 2000; Dietz & Bellizzi 1999; Malina & Katzmarzyk 1999). This study investigated whether there is a relationship between number of daily steps and BMI or overweight and obesity. For classification of overweight and obesity, definitions provided by Cole et al. (2000) were used because of their appropriateness for the population studied.

It is generally acknowledged that as physical activity increases, BMI decreases (Berkey et al. 2003; Vincent et al. 2003; Tudor-Locke et al. 2001; Lazarus et al. 1995); however, few studies have examined this relationship using pedometers. Conflicting results have been found with respect to the relationship between step counts and BMI, with limited, modest, and statistically significant predominating inverse relationships (Tudor-Locke et al. 2004; Vincent et al. 2003; Tudor-Locke et al. 2001). Only one known study has determined a cutoff point of pedometer steps/day as an indication of overweight and obesity; for primary school girls, obtaining a minimum of 12,000 steps/day was revealed as the cutoff point in determining the like-lihood of overweight or obesity (Tudor-Locke et al. 2004). There is no data on the relationship between pedometer-determined step counts and BMI in the female, grades 8–10, adolescent Australian population.

Physical self-esteem

In addition to BMI, there is a need to better understand the determinants of physical activity in youth. As perceived competence theory suggests, perceptions that the children hold of themselves may be important motivational influences for current and future physical activity (Biddle et al. 1993). Through the study of self-perception, important findings for the motivational determinants of physical activity in adolescents can be explored. The possession of positive feelings of self-worth or high self-esteem has been considered

important, not only as an index of mental well-being but also as a mediator of behavior (Fox 1988). Research shows that the self-esteem is associated with positive achievements and socially related behaviors such as leadership ability, satisfaction, decreased anxiety, and improved academic and physical performance (Hayes et al. 1999). Such research has highlighted the importance of self-esteem in physical education and exercise programs (Biddle et al. 1993).

Self-esteem has been identified as multidimensional and hierarchical in structure (Shavelson, Hubner & Stanton, 1976).

> Multidimensionality necessitates a profile approach to instrument design so that separate subscales assess each domain or dimension in addition to overall or global self-esteem (Fox & Corbin 1989, p.410).

Current self-esteem theories that emphasize this multidimensionality indicate that people have varied perceptions of themselves in different capacities (Marsh & Shavelson 1985). It is the self-perceptions in the different domains that are considered to contribute to an overall and more global sense of self-esteem (Hayes et al. 1999).

Fox and Corbin (1989) developed the physical self-perception profile (PSPP), which has enabled the physical component of self-esteem to be examined in more detail. They identified sports competence, physical condition, body attractiveness, and strength competence as distinct sub-areas, and these were shown to be the subordinates to global physical self-esteem and global general self-esteem in a hierarchical organization (Figure 1). However, as this model was established with young college students, further modifications by Whitehead (1995) enabled the model to be used with children and adolescents, renaming it as the Children and Youth Physical Self-Perception profile (CY-PSPP). This is the questionnaire used in this study to identify the psychological factors that have a relationship with physical activity levels among female adolescents.

Through the CY-PSPP, research has suggested that a relationship exists between physical self-perceptions, physical activity level, and BMI. Crocker et al. (2000), in a study on children and adolescents, found that physical self-perceptions are related to physical activity. Based on motivation theories, which state that people are drawn toward activities in which they can demonstrate a high degree of skill or competence (Hayes et al. 1999), it follows that physical self-perceptions should be positively related to levels of physical activity. With respect to self-perceptions and BMI, research found that a number of psychological variables were related to increased BMI (Kolody & Sallis 1995). Physical activity preference, activity attitude, physical activity competence, self-concept and body image, which were negatively correlated with BMI, increases. Thus, it is hypothesized that physical self-perceptions will decrease as physical activity levels decrease.

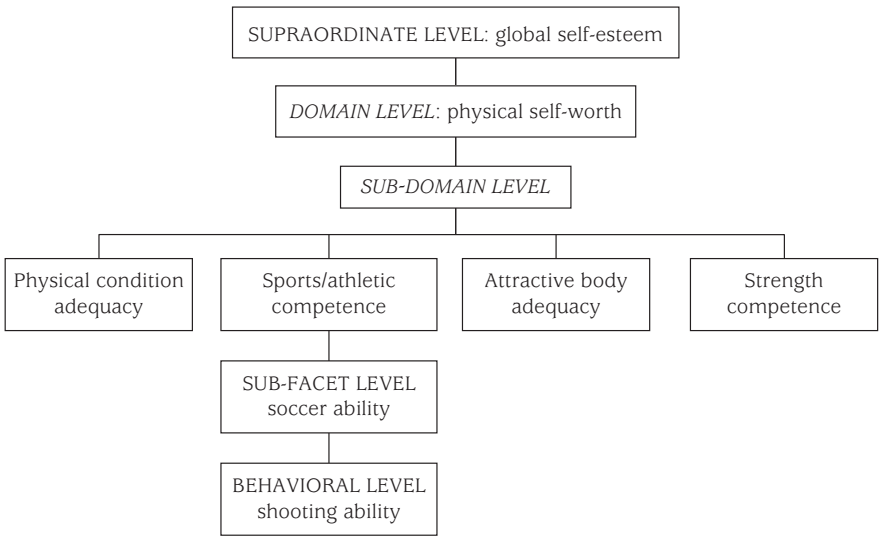

Fig. 1 Multidimensional and hierarchical structure of self-esteem (after Shavelston & Hubner 1976).

This study identified the age at which physical activity levels begin to decline in Australian female adolescents and investigates the possible relationship between physical activity levels, BMI, and physical self-esteem.

Methods

Participants

Participants were 297 adolescent females in grades 8–10 (grade 8, $n = 108$; grade 9, $n = 93$; grade 10, $n = 96$) who attended a nonstate/private high school in Southeast Queensland, Australia. Participants volunteered to be involved in the study and were required to provide written parental consent before research commenced.

Pedometers (step counts)

Yamax Digi-Walker SW-701 pedometers were used to determine the participants' total daily steps. Participants placed the pedometer on the waistband above the right knee every morning and wore the pedometer until they went to bed. The pedometer was then worn again the next morning and this procedure was repeated for a period of 5–8 days. Instructions were given to carryout normal physical activities and to remove the pedometer only when swimming or showering. Each participant was allocated a number that corresponded to a number on the pedometer for ease of data collection, analysis and participant confidentiality. During the first school lesson of each day the class teacher recorded whether or not the pedometer had been worn the previous day and the total number of steps taken. Researchers calculated the mean daily steps by calculating total steps taken divided by the number of days the pedometer had been worn.

BMI

Height (to nearest 0.1 mm) and weight (to nearest 0.1 kg) measurements were taken by school physical education teachers following the International Society for the Advancement of Kinanthropometry (ISAK) protocols and procedures. Height was taken using a stadiometer and weight using electronic scales provided by the research team. Equipment (stadiometer and scales) was calibrated before each session following ISAK protocols and procedures. Participants wore standard physical education clothing while measurements were taken. Researchers then calculated BMI ($kg\,m^{-2}$) using the obtained height and weight measurements.

Physical self-esteem

The CY-PSPP was used to assess the participants' perceptions of competence in the physical domain. Participants filled out the questionnaire in their peer assembly sessions. The room was set up so that the participants were spread out in the classrooms. Before the questionnaire was handed out to all participants were guided through a practice question to prevent questionnaires from being filled out incorrectly. The procedures of the CY-PSPP were then explained to all participants and were reassured that the questionnaire was not a test. Confidentiality was assured as participants placed their pedometer number on the questionnaire. They were then requested to follow the questionnaire as each question was read aloud slowly and clearly. Participants were free to ask questions about the questionnaire at any stage. Through the use of a number system, the data was then collated with BMI and step counts and analyzed.

Design and analysis

University Human Research Ethics was sought and approved. All data collection occurred at the same time of the school year. The school at which data collection was carried out volunteered to be involved in the study (convenience sample).

All data, parametric and descriptive (means and standard deviations) were reported. Analysis of variance using grade level as the grouping variable was conducted. Further, correlations of continuous dependent variables were also performed.

Results

Pedometers (step counts)

The Table shows the mean ± SD steps/day for each grade level. Comparison of the mean daily steps for each grade level revealed a significant difference in mean daily steps between grades 8 and 10 [$F(2, 294) = 3.562$,

$p < 0.05$]. These results would suggest that mean steps/day decrease with age and that a significant drop-off in habitual physical activity (pedometer step counts) occurs in grade 10 (approximately 15 years of age). The SD is greater in grade 10. The "low activity level" girls in grade 10 were more sedentary by over 1700 steps/day (approximately 17 min day^{-1}, 119 min week^{-1}, 510 min month^{-1}, 6188 min year^{-1}).

BMI

Analysis of correlations between mean daily steps and BMI, [$F(1, 295) = 36.057$, $p < 0.0001$, $r = -0.251$], indicate a significant negative correlation between the two variables. Figure 2 shows that as mean step count increases, BMI decreases (or the reverse).

Results of using the identified cutoff point of 12,000 steps/day for primary school-aged girls (Tudor-Locke et al. 2004) for identification of overweight and obesity (Cole et al. 2000) are shown in Figure 3. Participants taking <12,000 steps/day had a mean BMI of 24 kg m^{-2} whereas participants taking >12,000 steps/day had a mean BMI of 21 kg m^{-2}. Therefore, it was found that adolescents taking <12,000 steps/day had a higher mean BMI and were more likely to be classified as overweight.

Table Mean ± SD steps/day for adolescents by grade level

Grade	*n*	Mean steps/day	SD
8	108	11.003	±2.989
9	93	10.803	±3.030
10	96	9.864	±3.587

Physical self-esteem

Correlations between physical self-perceptions and BMI indicated significant negative correlations between BMI and physical condition ($r = -0.280$, $p < 0.01$), sports competence ($r = -0.144$, $p < 0.05$) and physical self-worth ($r = -0.207$, $p < 0.01$), with attractive body ($r = -0.325$, $p < 0.01$) being the most significant. A positive correlation existed between BMI and strength competence ($r = 0.180$, $p < 0.01$).

Activity levels were split into low, middle, and most active groups. Analysis of physical activity levels and perceived competence scales revealed a significant difference. All means for self-perceptions (Figure 4) are higher for higher physical activity levels except global self-worth.

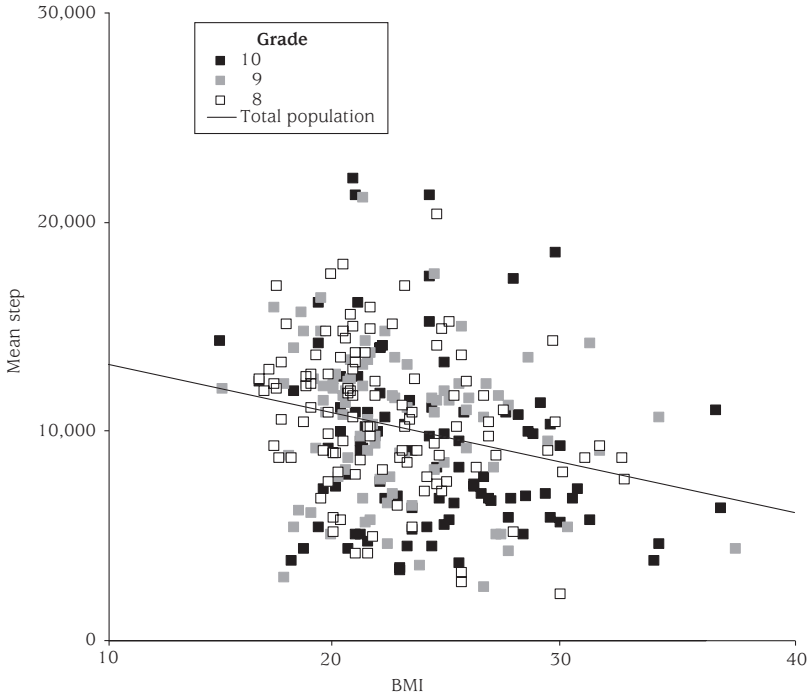

Fig. 2 Relationship between mean daily steps and BMI.

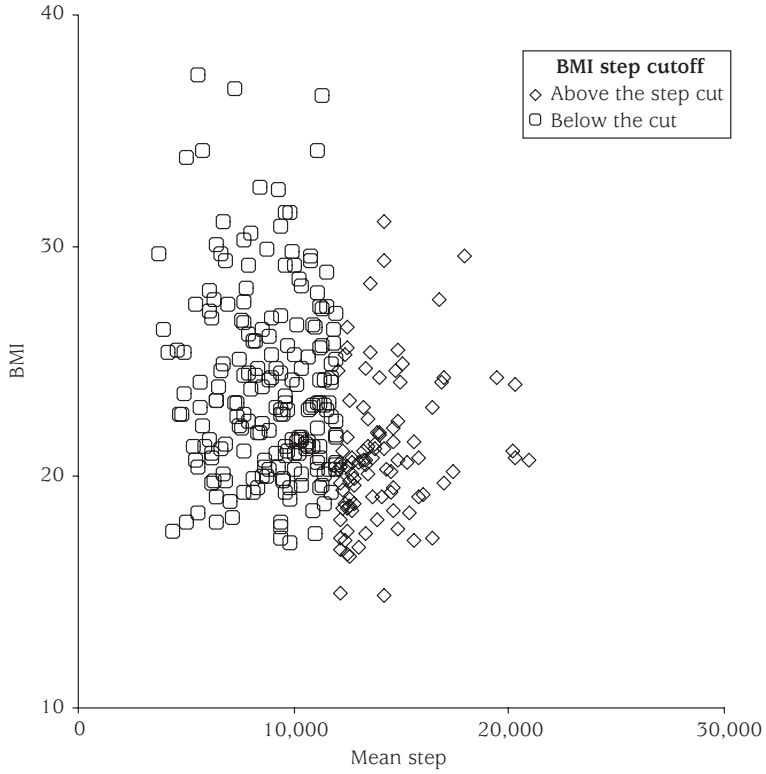

Fig. 3 Relationship between BMI and 12,000 steps/day.

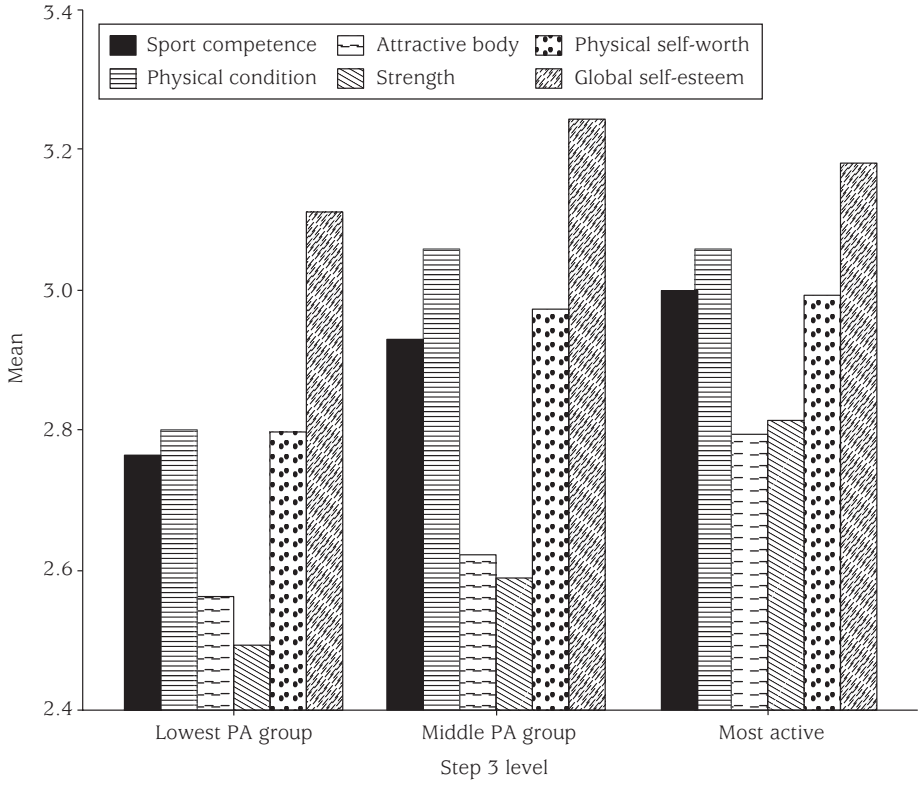

Fig. 4 Comparison of perceived competence scales with physical activity level.

Discussion

Pedometers (step counts)

Obesity levels are rising at an alarming rate, both worldwide and in Australia. This can largely be attributed to a positive energy balance which is the result of an increase in energy input coupled with a decrease in energy output (Australasian Society for the Study of Obesity 2004a,b). Our results would indicate that habitual physical activity (energy output) levels decrease from grade 8 to 10, dropping off significantly in grade 10 (approximately 15 years of age). Measurement of pedometer-determined steps/day on Australian children would indicate that our presented mean and SD are in reasonable agreement with USA and Swedish results (Vincent et al. 2003). Research has determined that values between 7000 and 13,000 steps/day should be expected of healthy younger adults, and our results confirm this expectation (Tudor-Locke & Myers 2001).

Despite the lack of Australian pedometer-determined habitual physical activity levels on adolescents, other research conducted using various measurement instruments (accelerometers, heart rate monitors, self-reports, and direct observation) does indicate that physical activity levels decline most significantly during the adolescent years (Thompson et al. 2003; Kimm et al. 2002; Caspersen et al. 2000; Sallis 2000; Sallis et al. 2000; Telama & Yang 2000; Van Mechelen et al. 2000). Since research has also found pedometer-determined step counts to be highly correlated with walking speeds (54 –111.2 m min^{-1}), heart rate, oxygen uptake, and moderate-to-high physical activity (Crouter et al. 2003; Schneider et al. 2003; Freedson & Miller 2000), the raw data of pedometer step counts are an accurate, valid, and reliable measure of adolescents' habitual physical activity levels. The results of this study indicate that Australian adolescent girls partake in less habitual physical activity as they move from grade 8 to 10 and that this level of physical activity significantly decreases in grade 10, or at approximately 15 years of age. There may be many reasons for the occurrence of this phenomenon at this particular age. Increasing academic and extra-curricular activities may play a primary role in adolescents actively participating in less habitual physical activity. Curriculum change (e.g., eliminating required health and physical education) and restrictive school policies (e.g., regular uniforms not conducive to physical activity) may also lead to adolescents' decreasing physical activity levels during the school day. Research shows that primary school children do not compensate for increased physical activity during the school day by decreasing their physical activity levels after school (Dale et al. 2000). There is no evidence to believe that adolescents would do differently.

In a review of correlates of physical activity, variables that were found to be consistently associated with adolescents' physical activity levels were sex (male), ethnicity (white), age (inverse), perceived activity competence, intentions, depression (inverse), previous physical activity, community sports, sensations seeking, sedentary after school and on weekends (inverse), parent support, support from others, sibling physical activity, direct help from parents, and opportunities to exercise (Sallis et al. 2000).

The findings of this study that girls' physical activity declines over grades 8–10 and drops off significantly at grade 10 are important for all stakeholders with an interest in children's health. It is vital that physically inactive individuals and groups are identified. This will allow formulation of better school policies and appropriately targeted physical activity opportunities to curb the decrease in adolescents' physical activity levels and to engage those who are sedentary.

BMI

Physical activity levels are related to a variety of health outcomes. BMI is one of the most commonly used and widely accepted methods for assessing body composition in children and adolescents (Dietz & Bellizzi 1999; Lazarus et al. 1995). Although BMI is an indirect measure of adiposity, it is easily calculated from height and weight measures, which are inexpensive, noninvasive, convenient, harmless, reliable in screening settings, and practical for large-scale field work with children and adolescents (Lynch et al. 2000; Dietz & Bellizzi 1999; Lazarus et al. 1995). BMI has also been correlated with adiposity, total body fat, magnetic resonance imaging, dual energy X-ray absorptiometry, and percentage body fat (Lynch et al. 2000; Dietz & Bellizzi 1999). Therefore, BMI was an appropriate screening tool for assessing body composition in the population studied.

Despite the common use of this measure, there have been few studies investigating the possible relationship between step counts (pedometers) and BMI. A limited correlation between steps and BMI was found in one (Swedish girls) of the three (American, Swedish, and Australian) groups of children studied, and revealed that BMI increased as steps decreased (Vincent et al. 2003). On the other hand, a statistically significant inverse relationship between steps/day and body composition variables (BMI and percentage body fat) has also been found (Tudor-Locke et al. 2001). Further, recent work has found a modest correlation between BMI and steps/day (Tudor-Locke et al. 2004). In investigating the relationship between BMI and pedometer-determined step counts, this study found a significant negative correlation between the two variables. This shows that participants taking fewer steps had a higher BMI (as step counts decrease, BMI increases, or vice versa). This finding confirms the generally accepted belief that as physical activity levels decrease, BMI increases (Berkey et al. 2003).

If the number of pedometer-determined steps affects BMI, then there may be a dose–response relationship. Although this has not been directly studied, research on primary school girls has revealed that those taking $<$12,000 steps/day, or engaging in $<$120 min day^{-1} of activity are more likely to be classified as overweight or obese (Tudor-Locke et al. 2004). Although one should be cautious in applying this cutoff point to adolescents, analysis of our results would indicate that adolescent Australian girls taking $<$12,000 steps/day are also more likely to be classified as overweight.

These results inform healthcare professionals and those in charge of school day activities and curriculum, as well as physical educators who may have influence over implementation of adequate physical activity opportunities that may be beneficial to female adolescents in terms of BMI.

Physical self-esteem

Extensive research has been conducted in regard to the area of self. Of particular interest to this study is the relationship between physical self-perceptions and physical activity. Interest in this relationship has been encouraged by the important role of self-concept in the explanation of human well-being, and its role as an initiator and mediator of human behavior (Marsh 1993). Based on motivation theories which state that people are drawn toward activities in which they can demonstrate a high degree of skill or competence (Hayes et al. 1999), it makes sense that physical self-perceptions should be positively related to levels of physical activity.

This study investigated this relationship and found that female adolescents who are more physically active score higher on all psychological variables and, therefore, have a higher physical self-worth than those who are less active. This is consistent with previous research conducted by Crocker et al. (2000), who found that physical self-perception is a correlate of physical activity in older children.

A question that remains unanswered is whether adolescents engage in physical activity because they have high self-perceptions, or have high self-perceptions because of their participation in physical activity. Further research to investigate this causal link between self-perceptions and physical activity is warranted. Since self-esteem has been associated with healthy psycho-social function across various domains, its role in promoting, maintaining, and enhancing participation in physical activities among children and adolescents needs to be clearly established. Understanding this link will assist practitioners in developing effective intervention programs.

Current research suggests that self-perceptions in different domains contribute to an overall, and more global, sense of self-esteem (Harter 1978). These different domains are: academic, social, physical, and emotional. The structure of these domains is hierarchical structure (Shavelson et al. 1976). Each of these domains are fed by sub-domains of self-perceptions such as perceived math or reading ability in the academic domain, or perceived sport ability and appearance in the physical domain. The interaction of different domains modify the more enduring and global elements of self-esteem. The fact that someone does not place high importance on the physical domain does not mean that their self-esteem is any less than someone who does, as they still place high importance on another domain, such as the academic domain (Shavelson et al. 1976). This explains why the

findings of this study show no significant difference in overall global self-worth between the most physically active group compared to the least physically active group. Therefore, regardless of physical activity level, global self-esteem may be the same for all groups, as it is affected by various other domains.

In general, those individuals with a higher body weight have lower self-esteem than those who have a lower body weight. Research has found (Kolody & Sallis 1995) a number of self-esteem and other psychological variables (Pesa et al. 2000) to be associated with increased BMI. Of the seven cross-sectional studies on the association between obesity and self-esteem among adolescents, three reported that an inverse relationship existed between BMI and self-esteem, and one reported no relationship. On investigating the relationship between BMI and self-perceptions, this study found a negative correlation between all subscales except for strength, which showed a positive correlation. This indicates that participants with a higher BMI have lower self-perceptions than those with lower BMI. The finding that participants with higher BMI actually have higher self-perceptions in terms of strength than those with lower BMI suggests that those adolescents who have higher BMIs have more positive strength perceptions than those who have lower BMIs. The subscale which was most significantly related to BMI was attractive body, indicating that those adolescents who have lower BMIs have more positive body attractiveness perceptions than those with higher BMIs. These findings are consistent with Cok (1990) who found that high school students who participated in physical activity programs had a higher mean body image satisfaction score than nonparticipants. This study found that a significant association exists between BMI and self-esteem, indicating that girls in grades 8–10 with a higher BMI have lower self-esteem.

Limitations

There are limitations to the use of pedometers that may affect the results obtained. Certain walking speeds, amount of abdominal adiposity, and type/make/model of pedometer affect the instrument's accuracy and reliability (Crouter et al. 2003; Schneider et al. 2003; Tudor-Locke & Myers 2001; Bassett et al. 1996). Pedometers also must be removed during swimming activities. It is generally accepted that pedometers are insensitive to many forms of activity (cycling, stair climbing, static heavy lifting, and general upper body movements) (Trost 2001; Freedson & Miller 2000; Welk et al. 2000; Kilanowski et al. 1999; Eston et al. 1998). This may mean that the indication of habitual physical activity levels given in this study possibly underestimates the actual total habitual physi-cal activity levels of adolescents. While pedometers also provide valuable information about the volume of cumulative work, generally speaking they do not offer information about the frequency, intensity or duration of activity, dimensions which may be useful in determining the exact health benefits of physical activity (Trost 2001; Freedson & Miller 2000; Welk et al. 2000; Kilanowski et al. 1999; Eston et al. 1998). It should also be noted that there are problems in comparing different studies that have used different types and models of pedometers, because spring tensions within the devices affect their sensitivity to detect activity (Freedson & Miller 2000).

With respect to BMI, it must also be noted that it has a high specificity and a low sensitivity (Malina & Katzmarzyk 1999; Lazarus et al. 1995).

Although there are a number of strengths of using BMI as an indication of body composition in adolescents, there are some limitations too. Level of physical activity is not the only factor that affects BMI (Lynch et al. 2000; Dietz & Bellizzi 1999; Malina & Katzmarzyk 1999; Lazarus et al. 1995). Variables such as nutrition, genetics, ethnicity, and sexual maturation also affect the body composition, thus affecting BMI, and hence were not investigated in this study (Lynch et al. 2000; Dietz & Bellizzi 1999; Malina & Katzmarzyk 1999; Lazarus et al. 1995). One must also be cautious in using this measure on different ethnic populations and adolescents due to differing subcutaneous fat distribution, percentage body fat, time and tempo of peak height velocity, and sexual maturation (Lynch et al. 2000; Dietz & Bellizzi 1999; Malina & Katzmarzyk 1999). BMI cutoff values are most often North American values; however, a worldwide standard definition for child overweight and obesity has been established (Cole et al. 2000). Readers are referred to this comprehensive study for BMI readings of overweight and obesity for gender and age (Cole et al. 2000), which were utilized in this study for girls aged 13–15 years (Denney-Wilson et al. 2003; Cole et al. 2000).

The use of these definitions revealed that female adolescents taking less mean daily steps were more likely to be classified as overweight or obese.

Previous research has been conducted in relation to physical self-perceptions and gender (Hayes et al. 1999; Marsh 1998; Sonstroem 1998). As this study comprised only females, differences that may exist between genders need to be investigated further. This study focused only on adolescents from a nonstate/private secondary school. In order to identify possible relationships between social status and physical activity levels, future research needs to investigate adolescents from state/public secondary schools.

Conclusion

With obesity levels rising and a decrease in children and adolescents' physical activity levels being evident, it is imperative that all stakeholders with interest in children's health work toward developing opportunities to encourage and support daily participation in physical activities.

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