2011

Proficiency deficiency: mastery of fundamental movement skills and skill components in overweight and obese children

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Publication Details

Cliff, D. P., Okely, A. D., Morgan, P. J., Jones, R. A., Steele, J. R. & Baur, L. A. (2011). Proficiency deficiency: mastery of fundamental movement skills and skill components in overweight and obese children. Obesity, (July),

Proficiency deficiency: Mastery of fundamental movement skills and skill components in overweight and obese children

RUNNING HEAD: Skill and component mastery in obese children

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I am happy for my email address to be published.
There are no conflicts of interest, financial or otherwise, of any of the authors.

* The manuscript includes 4 tables.

The study was part of a project funded by the National Health and Medical Research Council of Australia (354101).

ABSTRACT

The purpose of this observational study was to compare the mastery of 12 fundamental movement skills (FMS) and skill components between a treatment-seeking sample of overweight/obese children and a reference sample from the United States (US). Mastery of 6 locomotor and 6 object-control skills (24 components in each sub-domain) were video-assessed by one assessor using the Test of Gross Motor Development II (TGMD-2). The 153 overweight/obese children (mean ± s.d. age = 8.3 ± 1.1 years, BMI *z*-score = 2.78 ± 0.69, 58% girls, 77% obese) were categorized into age groups (for the underhand roll and strike: 7-8 years and 9-10 years; all other FMS: 6-7 years and 8-10 years) and mastery prevalence rates were compared with representative US data (N = 876) using chi-square analysis. For all 12 skills in all age groups, the prevalence of mastery was lower among overweight/obese children compared with the reference sample (all $P < 0.05$). This was consistent for 18 locomotor and up to 21 object-control skill components (all $P < 0.05$). Differences were largest for the run, slide, hop, dribble and kick. Specific movement patterns that could be targeted for improvement include positioning of the body and feet, the control or release of an object at an optimal position, and better use of the arms to maintain effective force production during the performance of FMS. Physical activity programs designed for overweight and obese children may need to address deficiencies in FMS proficiency to foster the movement capabilities required for participation in heath-enhancing physical activity.

Abstract word count: 250

Key words: adiposity, exercise, physical activity, child development, childhood obesity

INTRODUCTION

Childhood obesity is considered a public health priority worldwide (1) because of high prevalence rates internationally (2), and because of the serious and diverse short- and long-term health consequences associated with pediatric obesity (3). Physical inactivity has an influential role in the development of childhood obesity (4) and thus, may be important in treatment and prevention efforts. Overweight and obese children are less active than their non-overweight counterparts (5), and higher body fat percentage appears to be predictive of lower physical activity participation in childhood (6). Consequently, overweight children may become caught in a perpetuating cycle of physical inactivity and unhealthy weight-gain.

One potential mechanism affecting this weight-gain cycle is movement competency, or Fundamental Movement Skill (FMS) proficiency (7). FMS represent the foundational skills required to participate in many physical activities, and include locomotor skills (e.g., running, jumping, and hopping) and object-control or manipulative skills (e.g. catching, throwing, and kicking). Cross-sectional studies among preschoolers (8, 9), children (10, 11), and adolescents (12) have identified FMS proficiency as an important correlate of physical activity participation (13). This appears to also be the case for overweight children (14). Notably, recent longitudinal evidence indicates that childhood motor proficiency is predictive of adolescent physical activity (15). Additionally, FMS competency is positively associated with cardio-respiratory fitness (16, 17), and perceptions of physical or sports competence (18) among children and adolescents (13).

Overweight and obese children and adolescents also have poorer FMS proficiency than their non-overweight counterparts, and the differences appear to be more apparent for locomotor skills than object-control skills (19-21). However, these studies have not described the specific differences in a variety of individual FMS (both locomotor and object-control skills) or specific components of individual skills that are contributing to the gap in movement proficiency between overweight and non-overweight children. The development of interventions to enhance movement skill competency and physical activity among overweight and obese children would be better informed by a more detailed understanding of the specific FMS and the associated movement patterns which overweight and obese children have the most difficulty mastering. Therefore, the purpose of this study was to compare the mastery of 12 FMS and their components between overweight and obese children and a reference sample from the US. We aimed to test the hypothesis that the prevalence of mastery would be lower among overweight/obese children compared with reference data for locomotor skills and their components, but not object-control skills. If differences were apparent, we aimed to identify the skills and skill components where the greatest differences existed, and therefore those that might require targeting through interventions among overweight and obese children.

METHODS AND PROCEDURES

Participants

One-hundred and sixty-five overweight or obese children aged between 5.5-10 years were recruited, as part of the multi-site Hunter Illawarra Kids Challenge Using Parent Support (HIKCUPS) trial (22). Only baseline data were used for the current analyses. Participants were recruited from communities surrounding the Universities of Wollongong and Newcastle, New South Wales, Australia, using a number of methods such as advertisements in school newsletters and community newspapers. Eligibility criteria included the child being overweight or obese (referred to hereafter as overweight/obese) according to International Obesity Task Force cut points (23), aged 5.5-10 years, pre-pubertal (Tanner Stage I) and generally healthy. Children with extreme obesity (BMI *z*-score > 4.0), known syndromal causes of obesity, medications known to be associated with weight gain, chronic illness, who had started puberty (parent reported – Tanner staging) or significant dietary restriction were excluded. The Human Research Ethics Committees at both sites approved the study protocol. Written informed consent was obtained from each child's parent or carer, as well as child assent. The HIKCUPS RCT is registered with the U.S. National Centre for Clinical Trials Registry (NCT00107692).

Measurement of adiposity

Height and weight were measured using standardized procedures, which have been reported in detail elsewhere (22, 24). *Z*-scores for BMI (kg/m^2) were calculated using United Kingdom reference data (25), as reference data for Australian children are not available.

Assessment of fundamental movement skill proficiency

The Test of Gross Motor Development II (TGMD-2) (26) was used to assess children's FMS proficiency. Comprehensive process-measures of FMS, such as the TGMD-2 are uniquely designed to capture the topographical aspects or components of each skill (see Tables 3 and 4 for examples), and are therefore useful to detect and correct errors in the movement pattern in order to foster efficient and effective performance of FMS. The TGMD-2 comprises six locomotor skills - run, gallop, hop, leap, horizontal jump (hereafter referred to as jump) and slide - and six object-control skills - striking a stationary ball (strike), stationary basketball dribble (dribble), catch, stationary kick (kick), overhand throw (throw) and underhand roll (roll) and has established validity and reliability in 3- to 10-year-old children (26). The test was administered in small groups ($n \leq 4$) following standardized procedures, instructions and demonstrations (14, 27). Children were given a standardized visual demonstration of the correct technique for performing the skill before each test, but were not told what components were being assessed. Children completed two trials of each skill, which were recorded using a digital video camera (Sony DCR2-HC52 Mini DV, Japan) to allow for greater measurement scrutiny during analysis.

One trained assessor who was blinded to the purpose of this study assessed children's FMS after demonstrating ≥ 80% inter- and intra-observer reliability on pre-coded videotapes, as previously described (14, 27). The assessor scored the performance components of each skill as present ("1") or absent ("0") for each of the two trials. Scores for each trial were summed to give total component scores, and these were summed to give total skill scores. The conventional method of reporting the prevalence of FMS is to report the proportion of individuals who have mastered all components of a skill. However, because this is a dichotomous categorization method, it could exaggerate the apparent differences when comparing overweight/obese and reference samples if there were a large proportion of overweight/obese children who were close to achieving mastery. Therefore, we calculated the proportion of the overweight/obese sample exhibiting mastery (defined as exhibiting all skill components during both trials, e.g., run = 8/8) and advanced skill proficiency (defined as exhibiting all or all but one component during both trials, e.g. run ≥ 7/8) (28) for each skill. The proportion of overweight/obese children exhibiting mastery of each skill component (e.g., run, component 1 = 2/2 trials) was also calculated. Total skill scores were summed to provide raw scores for the locomotor and object-control skill sub-tests. Using the TGMD-2 conversion tables which are based on US representative reference data (26), sub-test raw scores were converted to locomotor and object-control standard scores. In the TGMD-2, sub-test standard scores are age-adjusted, and the object-control skill standard score is also adjusted for sex because boys were found to be more proficient than girls at object-control skills in the TGMD-2 reference sample (26). Standard scores were summed and converted to calculate each child's gross motor quotient (26).

The proportion of the overweight/obese sample exhibiting mastery/advanced skills for each FMS and skill component was then compared to the TGMD-2 reference sample (n = 876 for 6-10 years), which is representative of the US population in regards to geographic region, sex, ethnicity, rural or urban residence, parent education and disability (26). US reference data were used because equivalent data on Australian children are not available for the TGMD-2. The TGMD-2 reference data set was considered appropriate for the comparative analyses in this study for two reasons. First, most of the FMS assessed in the TGMD-2 are included in Australian primary school physical education curricula (29). Second, a recent study used the TGMD-2 to assess FMS proficiency among 4-year-old Australian children (30). In this study, Australian children exhibited similar levels of FMS mastery to the US reference sample. Therefore, it was unlikely that cultural differences in the mastery of the specific FMS assessed in the TGMD-2 would be responsible for the hypothesized lower prevalence of FMS mastery in Australian overweight/obese children compared to the US reference sample.

Statistical analyses

All analyses were carried out using SPSS version 16.0. Descriptive statistics were calculated for the total sample and by sex, and reported as means (± s.d.) for normally distributed variables, and the median (± interquartile range) for those that were not normally distributed. Sex differences for descriptive outcomes were tested using independent samples *t*-tests and Mann-Whitney *U* tests. As FMS proficiency increases with age throughout childhood (26), participants were categorized into age groups for the analyses to provide appropriate comparisons. Age groups were formed because of small samples for 6- (n = 20) and 10-year-olds (n = 3). Adjacent ages (e.g. 6 and 7 years) with the most similar proportions of participants exhibiting mastery for each individual skill in the TGMD-2 reference sample were combined. For 10 of the 12 skills and for all of the skill components, the most appropriate combined age groups were 6-7 years and 8-10 years. For the strike and roll the differences in mastery prevalence in the TGMD-2 reference sample between 6- and 7-year-olds were larger than between 7- and 8-year-olds (strike: 6 years = 21%, 7 years = 35%, 8 years = 41%; roll: 6 years = 21%, 7 years = 37%, 8 years = 38%), so for these skills the age groups were categorized as 7-8 years and 9-10 years. Due to the age categories constructed for these analyses, children aged < 6 years (n = 6) were excluded. The final sample included the following numbers for each age: 6 years (n = 20), 7 years, (n = 37), 8 years (n = 43), 9 years (n = 50), and 10 years (n = 3). Combined age groups were considered particularly appropriate for 8-10-year-olds because the difference in mastery prevalence between 8- and

10-year olds in the reference sample was ≤ 4% for four of the six locomotor skills (leap = 12%, slide = 11%) and was ≤ 8% for four of the six object-control skills (catch = 11%, dribble = 23%) (26). Children aged 10 years were not excluded because the differences in mastery prevalence between 9- and 10-year-olds in the reference sample were small (≤ 5% for all locomotor skills and ≤ 7% for all locomotor components; ≤ 7% for all object-control skills and ≤ 8% for all object-control skill components) (26).

The prevalence of mastery for each age group from the TGMD-2 reference sample was then calculated by averaging the proportions for each age. Differences in mastery prevalence between the overweight/obese and reference samples were tested using chi-square analysis. Results were considered statistically significant at $P < 0.05$, or where the prevalence of mastery/advanced skills in the overweight/obese sample was 0% and substantially lower (≥ 20%) than the TGMD-2 reference sample. The second criterion for statistical significance was devised post-hoc because of low prevalence rates in the overweight/obese sample, and the value was chosen because we considered a 20% difference to be both behaviorally significant and conservatively large. Our findings supported the use of this criterion, as an 11% difference between groups was not statistically significant ($P < 0.062$) but a 23% difference was ($P < 0.001$), for the smallest sub-group ($n = 57$).

RESULTS

Data for 153 overweight/obese children were available and included in the analyses (Table 1). Seventy-seven percent of participants were categorized as obese, and boys had a higher BMI *z*-score than girls. When sex differences were examined for raw sub-test scores, boys were better performers of object-control skills whereas girls were more proficient at locomotor skills. Relative to the TGMD-2 reference sample, the boys' standard scores indicated that they ranked in the bottom < 1% for locomotor and object-control skills. Girls' standard scores for both sub-tests were significantly higher than boys, although girls still ranked in the bottom 1% for locomotor and object-control skills (28). Gross motor quotient scores indicated that both boys and girls ranked in the bottom < 1% for overall FMS proficiency (28).

The prevalence of mastery was significantly lower in the overweight/obese sample compared to the reference sample for all 12 skills across all age groups (all $P < 0.05$, Table 2). For 6-7-year-olds, no child in the overweight/obese sample exhibited mastery for seven out of 10 FMS, compared to 25%-78% of the reference sample. Likewise, for three out of 10 FMS, no overweight/obese child in the 8-10-year-old age group exhibited mastery, compared to 44%-85% of the reference sample. For the strike and the roll, no child in the overweight/obese sample in the 7-8- or 9-10-year-old age groups exhibited mastery, compared to 38%-48% of the reference sample. Among the younger age group, the prevalence of mastery was: i) ≥ 60% lower for the run and slide, ii) between 30% and 59% lower for the gallop, jump and hop, and the dribble, kick, strike and roll, and iii) between 23% and 29% lower for the leap catch and throw. Among the older age group, the prevalence of mastery was: i) more than 75% lower for the run and slide, ii) between 50% and 75% lower for the gallop and hop, and the dribble, catch, kick and throw, and iii) between 40% and 49% lower for the leap and jump, and the strike and roll. For 10 skills across all age groups, the prevalence rates for mastery and advanced skills were similar among overweight/obese participants (Table 2). The exceptions were for the catch (6-7 years: 14% vs. 32%, and 8-10 years: 26% vs. 53%, for mastery and advanced skills respectively), and to a lesser degree the kick (6-7 years: 4% vs. 11%, and 8- to 10-years: 2% vs. 14%, for mastery and advanced skills respectively). However, excluding the catch for 6-7-year-olds, the prevalence of advanced skills was significantly lower in the overweight/obese sample compared to the prevalence of mastery in the reference sample for all skills across all age groups (Table 2).

Of the 24 locomotor skill components, the prevalence of mastery in the overweight/obese sample was significantly lower than the reference sample for 18 components among both 6-7-year-olds and 8-10-year-olds ($P < 0.05$, Table 3). The components where the prevalence of mastery was not significantly lower in the overweight/obese sample were those relating to use of the feet or footwork during the movement skill. The prevalence of mastery among 6-7-year-olds was significantly higher in the overweight/obese sample compared to the reference sample for leap (Component 1 (C1)): "Take off on one foot and land on the opposite foot" (88% vs. 74%). Likewise, among both 6- to 7-year-olds and 8-10-year-olds, the following components did not differ significantly between the overweight/obese and reference samples: run (C2), gallop (C3), leap (C2), and slide (C3). For the hop (C2) among 6-7-year-olds, and for the leap (C1) and slide (C4) among 8-10-year-olds, prevalence rates were also not found to differ significantly between groups. In contrast, the prevalence of mastery of six components relating to the effective use of the arms were found to be between 36% and 90%, and between 54% and 94% lower in the overweight/obese sample compared to the reference sample for 6-7- and 8-10-year-olds, respectively: run (C1), gallop (C1), hop (C3), leap (C3), and jump (C2 and C4). Likewise, the prevalence of mastery was between 48% and 74%, and between 50% and 82% lower in the overweight/obese sample compared to the reference sample for 6-7- and 8-10-year-olds, respectively, in the following areas: landing on the toes or the heel (run C3), foot positioning (gallop C2 and slide C2), use of the leg for force production (hop C1), use of the non-preferred foot for explosive power (hop C5), and upper-body positioning (slide C1).

Of the 24 object-control skill components, the prevalence of mastery in the overweight/obese sample was significantly lower than the reference sample for 19 components among 6-7-year-olds and 21 components among 8-10-year-olds ($P < 0.05$, Table 4). The prevalence of mastery among both age groups was significantly higher in the overweight/obese sample compared to the reference sample for strike (C5): "Bat contacts ball" (91% vs. 66%, and 92% vs. 71%, respectively), and among 6-7-year-olds for strike (C1): "Dominant hand grips bat above nondominant hand" (98% vs. 87%). The prevalence of this latter component did not significantly differ for 8-10-year-olds. Likewise, prevalence rates were not found to differ significantly between the overweight/obese and reference samples for both age groups for: taking an elongated step immediately prior to kicking (kick C2), and among 6-7-

year-olds for using the fingertips during the dribble (dribble C2), and for the follow-through during the throw (throw, C4). The prevalence of mastery of 10 components, including all four for the roll, was between 43% and 87%, and between 55% and 92% lower in the overweight/obese sample compared to the reference sample for 6-7- and 8-10-year-olds, respectively. The areas of greatest difference in mastery prevalence were for: body (strike C2, throw C2, roll C1) and/or foot positioning (strike C2, kick C3, roll C2), controlling or releasing the object in an optimal position (dribble C1 and C3, roll C4), use of the arms to effectively generate force (throw C1, roll C1), bending the knees to lower the body (roll C3), and hip rotation to generate force (throw C2).

DISCUSSION

This study found that the prevalence of mastery of 12 FMS, 18 of 24 locomotor skill components, and between 19 and 21 out of 24 object-control skill components were significantly lower in a treatment-seeking sample of overweight/obese children compared with a reference sample of US children. Across age groups, the differences between the two samples were consistent and most prominent for four locomotor skills (run, slide, gallop, and hop) and two object-control skills (stationary basketball dribble and stationary kick). For most skill components differences were substantial, particularly those for locomotor skills relating to the effective use of the arms, landing on the toes or the heel, foot positioning, use of the leg for force production, use of the non-preferred foot for explosive power, and upper-body positioning. For object-control skill components, differences between the two samples were largest for: body and/or foot positioning, controlling or releasing the object in an optimal position, use of the arms to maintain effective force production, bending the knees to lower the body, and hip rotation to generate force. The magnitude of the deficiency in FMS proficiency exhibited by overweight and obese children in this study, where the prevalence of mastery was more than 40% lower than expected from reference data for all 12 FMS among 8-10-year-olds, is likely to be a pertinent behavioral barrier to physical activity participation and to achieving a healthier weight status.

To our knowledge, this is the first study to examine the prevalence of mastery of individual FMS among a large sample of overweight/obese children using a comprehensive and validated battery of 12 video-assessed skills. Previous studies of population samples have indicated that differences in FMS proficiency between overweight/obese and non-overweight children are predominantly due to discrepancies in locomotor skills, more so than object-control skills (19-21). For example, Okely and colleagues (19) assessed the run, jump, catch, throw, strike and kick in a large population sample of children and adolescents (*n* = 4,363). They found that overweight boys and girls in Grades 4, 6, 8, and 10 were less likely to possess advanced locomotor skills than their non-overweight peers. Differences by weight-status for object-control skills were apparent, but only for boys in Grades 6 and 10. Jones et al. (20) examined differences in FMS proficiency by weight status for the hop, gallop, skip, and throw among 9-year-olds (*n* = 692), and for the run, throw, catch, and strike among 11-year-olds (*n* = 722). Compared to their non-overweight peers, overweight/obese 9-year-old boys and girls were significantly less proficient at hopping, and overweight/obese 11-year-old boys and girls were significantly less proficient at running and throwing. Our study and others in this field (19, 20) are consistent in indicating that overweight and obese children exhibit deficits in locomotor skill proficiency relative to their peers.

In another study (31), real-time assessments of skill proficiency were conducted using the TGMD-2 to examine FMS mastery in a clinical sample of overweight/obese children (*n* = 132) aged 6-10 years. Consistent with the findings from the current study, the prevalence of FMS mastery was significantly lower in the overweight/obese sample compared to the TGMD-2 reference sample for the same six locomotor and six object-control skills assessed in this study. Therefore, the current study and one other (31) suggest that the differences in object-control skill proficiency by weight status among children might be larger than previously reported, particularly in clinical or treatment-seeking samples of overweight/obese children. In the current study, differences in mastery prevalence between the overweight/obese and reference samples were not as prominent for the catch and its components.

Previous studies have found that differences in catching proficiency between overweight and non-overweight children were small (20, 21). The smaller differences for this skill might be because catching is not as greatly inhibited by the musculoskeletal consequences of excess adiposity as other FMS.

The implications of low object-control skill mastery for overweight and obese children are noteworthy, because: i) proficiency in object-control skills in childhood predicts adolescent object-control skill proficiency (32), ii) childhood object-control skill proficiency predicts adolescent physical activity participation and fitness (15, 17), and iii) overweight and obese children's proficiency in object-control skills is associated with their physical activity participation, particularly among boys (14). There is limited evidence of effective strategies to promote long-term physical activity participation among overweight and obese children and adolescents (33). This might be partly due to the limited attention provided in treatment strategies to addressing overweight and obese children's poor FMS proficiency.

The larger differences between overweight/obese children and the reference sample reported in this study compared with other studies for FMS mastery, and particularly for object-control skill mastery, might be due to methodological differences. Previous studies have predominantly used live real-time FMS assessments, whereas FMS were assessed from video for the current analyses, which provides greater measurement scrutiny. Of the current sample, 77% of participants were classified as obese, which might also have contributed to the low mastery prevalence rates. Likewise, our participants were from a clinical sample, whereas in most other studies population samples of overweight/obese children have been examined. Our analyses were conducted using baseline data from a randomized controlled trial, and involved children whose parents/families were seeking treatment for their child's weight status and weight-related behaviors such as insufficient physical activity. It is, therefore, possible that the deficit in FMS mastery found in the overweight/obese sample in the current study might be more extreme than in population samples of overweight and obese children.

Consequently, our findings generalize to treatment-seeking overweight and obese children, and practitioners and health professionals assisting obese children to be more active and achieve a healthy weight status should be aware that low FMS proficiency is likely to act as barrier to many popular forms of organized and non-organized physical activity for these children.

The topographical mechanisms that might explain the lower prevalence of FMS mastery in the overweight/obese sample can be found in our analysis of the skill components. When grouping the skill components thematically, some of the patterns of movement in which overweight/obese children exhibited the greatest deficiency in mastery compared with the reference sample have plausible biomechanical origins. For example, overweight children typically have flatter and fatter feet compared to their non-overweight peers (34, 35), as well as increased foot pressures (36, 37) and pain (38), which potentially contribute to flat-footed ground contact during running (run C3). Lower relative knee extensor strength among obese children compared with their leaner counterparts (39) might also explain differences in force production and explosive power of the legs during hopping (hop C1 and C5) (40), and difficulties in bending the knees to lower the body during the roll (roll C3). Rectifying these inefficient and/or ineffective movement patterns among overweight and obese children may require initial weight loss to overcome the deleterious effect of excess adiposity on biomechanics (39, 41). However, low mastery of several skill components among overweight children might also be the consequence of low physical activity participation (41), and could be improved through active play, practice, and direction from physical education specialists. For example, positioning of the body and feet, the control or release of an object at an optimal position, and the use of the arms to maintain effective force production, are movement patterns that can be addressed through quality instruction using key teaching strategies such as demonstration, followed by developmentally appropriate practice, and skill-specific feedback. Such an approach can improve FMS among overweight and obese children in the short-term (27).

Our sample consisted of treatment-seeking overweight and obese children, so the generalizability of the findings might be restricted to those children enrolling in weight management programs. Australian reference data for the TGMD-2 are not currently available, therefore the comparisons provided may be limited by the use of US reference data. However, as we have discussed, it is unlikely that cultural differences in the mastery of the specific skills assessed explain the findings. Small participant numbers for some ages in the overweight/obese sample resulted in combining age groups to improve statistical power. Although directly comparing each individual age might be considered a more accurate method to examine differences between the groups, combining ages is unlikely to have influenced the findings because the prevalence of mastery for all FMS and most skill components was extremely low in the overweight/obese sample.

As the mastery of individual FMS and their components are not reported separately for boys and girls in the TGMD-2, we were not able to examine potential sex differences in the findings. The TGMD-2's locomotor and object-control skill standard scores and gross motor quotient use representative reference data to adjust for age and sex differences in FMS proficiency during childhood, so boys and girls would be expected to obtain similar scores. Relative to the reference sample, overweight/obese girls in our sample scored significantly higher on the standard scores and the gross motor quotient than boys, which may have influenced our findings. Compared to girls, boys had a higher level of adiposity, and this may have contributed to sex differences in FMS proficiency. These differences, however, might not be behaviorally or clinically meaningful because the overweight/obese girls and boys in our sample were both ranked very low for locomotor and object-control skill proficiency compared to the reference sample (i.e. in the bottom 1% or less). It is possible that FMS mastery might differ between overweight children and obese children. Due to the small number of overweight children in our sample, and the need to stratify the sample by age for comparative purposes, we were unable to adequately investigate differences in our findings by weight status. A limitation of this cross-sectional research is that we cannot elucidate whether low FMS proficiency influences the development of obesity among children by acting as a barrier to physical activity participation, or if obesity prevents physical activity participation among children, delaying or hindering FMS development. As both hypotheses are plausible, longitudinal research would assist in better understanding the causal and temporal nature of the relationships between FMS, physical activity, and obesity among children and adolescents.

Mastery of FMS and skill components were assessed from video by one assessor, using a validated process-measure that included a comprehensive battery of FMS, and these methodological procedures were strengths of this study. Of the previous studies comparing movement skill proficiency between overweight/obese and non-overweight children (19-21), most assessed FMS using live real-time assessments and multiple assessors, which might be more vulnerable to classification error and between-assessor variability compared with the procedures applied in this study. Likewise, most examinations in this area have assessed fewer skills than in the present study. The use of a process-measure, which evaluated the patterns of movement within each skill, allowed us to examine and identify the skill components with the lowest prevalence of mastery among overweight and obese children. This is a unique contribution of this study, and provides specific targets for physical activity promoters and practitioners to consider when attempting to enhance FMS proficiency among overweight and obese children. Another strength of our study was that our analyses included the additional and more flexible categorization of advanced skills for the overweight/obese sample. Evidently, the differences in mastery prevalence were not due to a large proportion of overweight/obese children being close to mastering the individual FMS examined.

The prevalence of FMS mastery was lower among overweight/obese children compared with reference data for all 12 FMS at each age group, and for 18 locomotor and between 19 and 21 object-control skill components. Participation in developmentally appropriate physical activity combined with instruction from physical education specialists can potentially play a role in enhancing overweight and obese children’s FMS proficiency (29). This study identified specific FMS and movement patterns that could be targeted by physical activity promoters for improvement among overweight and obese children. Physical activity programs designed for overweight and obese children may need to address deficiencies in FMS proficiency to foster the movement capabilities required for participation in health-enhancing physical activity.

ACKNOWLEDGEMENTS

Recruitment and data collection were completed as part of a National Health and Medical Research Council of Australia project grant (354101), and Dylan Cliff is funded by a National Heart Foundation of Australia – Macquarie Postdoctoral Research Fellowship (PH 09S 4603). We would like to thank the participating children and parents, local schools in the Hunter and Illawarra regions of New South Wales, and the Universities of Wollongong and Newcastle. We would also like to thank the Sanitarium Health Food Company for supplying the breakfast cereal for the assessments and Daniel Riethmuller for assisting with the FMS assessments.

DISCLOSURE

The authors declared no conflict of interest.

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Table 1 Descriptive characteristics of the overweight/obese sample

	All (n = 153)	Boys (n = 64)	Girls (n = 89)	P
Age, mean (s.d.), years	8.3 (1.1)	8.5 (1.0)	8.2 (1.1)	0.072
BMI, median (I.Q. range), kg/m^2	24.1 (22.2, 26.9)	25.2 (22.6, 27.0)	23.7 (21.6, 26.8)	0.088
BMI-z, mean (s.d.)	2.78 (0.69)	2.95 (0.66)	2.66 (0.69)	0.010[a]
Obese, % (n)	77 (118)	83 (53)	73 (65)	0.155
Locomotor skills raw score, mean (s.d.) (range 0-48)	24.1 (4.2)	22.9 (4.7)	25.0 (3.7)	0.003[a]
Locomotor skills standard score, mean (s.d.) (range 1-20)	2.9 (1.5)	2.5 (1.2)	3.2 (1.5)	0.002[a]
Object-control skills raw score, mean (s.d.) (range 0-48)	22.2 (5.4)	24.7 (5.2)	20.5 (4.8)	<0.001[a]
Object-control skills standard score, mean (s.d.) (range 1-20)	2.8 (1.6)	2.4 (1.5)	3.01 (1.6)	0.011[a]
Gross motor quotient, mean (s.d.) (range 46-160)	57.1 (8.0)	54.7 (7.1)	58.8 (8.2)	0.001[a]

BMI, body mass index.
[a]Significant difference between boys and girls, $P < 0.05$.

Table 2 Prevalence of FMS mastery in the reference sample and mastery and advanced skill proficiency in the overweight/obese sample

	6-7 years FMS mastery			6-7 years Advanced skills		8-10 years FMS mastery			8-10 years Advanced skills	
FMS	Reference sample (n = 311) (%)	Overweight/obese sample (n = 57) (%, n)	P	Overweight/obese sample (n = 57) (%, n)	P	Reference sample (n = 565) (%)	Overweight/obese sample (n = 96) (%, n)	P	Overweight/obese sample (n = 96) (%, n)	P
Locomotor										
Run	78	0 (0)	N/A	0 (0)	N/A	85	0 (0)	N/A	0 (0)	N/A
Gallop	43	0 (0)	N/A	0 (0)	N/A	55	1 (1)	<0.001[a]	2 (2)	<0.001[a]
Leap	25	0 (0)	N/A	0 (0)	N/A	45	0 (0)	N/A	2 (2)	<0.001[a]
Horizontal Jump	33	0 (0)	N/A	0 (0)	N/A	44	1 (1)	<0.001[a]	1 (1)	<0.001[a]
Slide	60	0 (0)	N/A	4 (2)	<0.001[a]	81	2 (2)	<0.001[a]	4 (4)	<0.001[a]
Hop	37	0 (0)	N/A	0 (0)	N/A	51	0 (0)	N/A	0 (0)	N/A
Object-control										
Stationary Basketball Dribble	31	0 (0)	N/A	0 (0)	N/A	66	3 (3)[b]	<0.001[a]	4 (4)[a]	<0.001[a]
Catch	43	14 (8)	<0.001[a]	32 (18)	0.062	77	26 (25)	<0.001[a]	53 (51)	<0.001[a]
Kick	34	4 (2)	<0.001[a]	11 (6)	<0.001[a]	65	2 (2)	<0.001[a]	14 (14)	<0.001[a]
Overhead Throw	25	2 (1)	<0.001[a]	5 (3)	<0.001[a]	52	1 (1)	<0.001[a]	4 (4)	<0.001[a]

	7-8 years FMS mastery			7-8 years Advanced skills		9-10 years FMS mastery			9-10 years Advanced skills	
FMS	Reference sample (n = 372) (%)	Overweight/obese sample (n = 80) (%, n)	P	Overweight/obese sample (n = 80) (%, n)	P	Reference sample (n = 358) (%)	Overweight/obese sample (n = 53) (%, n)	P	Overweight/obese sample (n = 53) (%, n)	P
Object-control										
Striking a Stationary Ball	38	0 (0)	N/A	4 (3)	<0.001[a]	48	0 (0)	N/A	2 (1)	<0.001[a]
Underhand Roll	38	0 (0)	N/A	0 (0)	N/A	41	0 (0)	N/A	0 (0)	N/A

FMS: fundamental movement skill; FMS mastery: possessing all skill components during two trials; Advanced skills: possessing all but one component during two trials. This category was used for the overweight/obese sample and compared against the prevalence of FMS mastery in the reference sample; N/A: Not applicable as the prevalence of mastery/advanced skill proficiency for the overweight/obese sample = 0%.

[a]Significant difference between groups ($P < 0.05$).

[b]n = 94 due to missing data.

Table 3 Prevalence of mastery of locomotor skill components in the reference and overweight/obese sample

	6-7 years Prevalence of mastery			8-10 years Prevalence of mastery		
Skill Component	Reference sample (%)	Overweight/ obese sample (*n* = 57) (%, *n*)	*P*	Reference sample (%)	Overweight/ obese sample (*n* = 96) (%, *n*)	*P*
Run						
C1. Arms move in opposition to legs, elbows bent	90	0 (0)	N/A	95	1 (1)	<0.001[a]
C2. Brief period where both feet are off the ground	99	100 (57)	-	99	100 (96)	-
C3. Narrow foot placement, landing on heel or toe (i.e., not flat footed)	94	40 (23)	<0.001[a]	97	47 (45)	<0.001[a]
C4. Nonsupport leg bent approximately 90 degrees (i.e., close to buttocks)	89	58 (33)	<0.001[a]	91	60 (58)	<0.001[a]
Gallop						
C1. Arms bent and lifted to waist level at takeoff	55	9 (5)	<0.001[a]	65	10 (10)	<0.001[a]
C2. A step forward with the lead foot followed by a step with the trailing foot to a position adjacent to or behind the lead foot	82	9 (5)	<0.001[a]	89	8 (8)	<0.001[a]
C3. Brief period when both feet are off the floor	95	98 (56)	0.261	96	99 (95)	0.139
C4. Maintains a rhythmic pattern for four consecutive gallops	87	70 (40)	<0.001[a]	92	81 (78)	<0.001[a]
Hop						
C1. Nonsupport leg swings forward in a pendular fashion to produce force	69	5 (3)	<0.001[a]	81	9 (9)	<0.001[a]
C2. Foot of non-support leg remains behind body	78	70 (40)	0.154	83	56 (54)	<0.001[a]
C3. Arms flexed and swing forward to produce force	60	7 (4)	<0.001[a]	74	0 (0)	N/A
C4. Takes off and lands three consecutive times on preferred foot	91	56 (32)	<0.001[a]	97	67 (64)	<0.001[a]
C5. Takes off and lands three consecutive times on other foot	85	37 (21)	<0.001[a]	93	43 (41)	<0.001[a]
Leap						
C1. Take off on one foot and land on the opposite foot	74	88 (50)	0.018	81	88 (84)	0.105
C2. A period where both feet are off the ground longer than running	84	86 (49)	0.686	93	90 (86)	0.190
C3. Forward reach with the arm opposite the lead foot	36	0 (0)	N/A	55	1 (1)	<0.001[a]
Horizontal Jump						
C1. Preparatory movement includes flexion of both knees with arms extended behind body	76	37 (21)	<0.001[a]	85	57 (55)	<0.001[a]
C2. Arms extended forcefully forward and upward reaching full extension above the head	46	0 (0)	N/A	59	1 (1)	<0.001[a]
C3. Take off and land on both feet simultaneously	82	63 (36)	<0.001[a]	87	72 (69)	<0.001[a]
C4. Arms are thrust downward during landing	74	4 (2)	<0.001[a]	89	10 (10)	<0.001[a]
Slide						
C1. Body turned sideways so shoulders are aligned with the line on the floor	67	2 (1)	<0.001[a]	87	5 (5)	<0.001[a]
C2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot	92	18 (10)	<0.001[a]	95	23 (22)	<0.001[a]
C3. A minimum of four continuous step-slide cycles to the right	92	90 (51)	0.482	95	97 (93)	0.399
C4. A minimum of four continuous step-slide cycles to the left	91	83 (47)	0.024	95	95 (91)	0.925

FMS: fundamental movement skill; FMS mastery: possessing skill component during two trials; N/A: Not applicable as the prevalence of mastery for the overweight/obese sample = 0%; -: Not applicable as the prevalence of mastery for the overweight/obese sample = 100%.
[a]Significant difference between groups ($P < 0.05$).

Table 4 Prevalence of mastery of object-control skill components in the reference and overweight/obese samples

Skill Component	6-7 years Prevalence of mastery Reference sample (%)	6-7 years Prevalence of mastery Overweight/ obese sample (n = 57) (%, n)	P	8-10 years Prevalence of mastery Reference sample (%)	8-10 years Prevalence of mastery Overweight/ obese sample (n = 96) (%, n)	P
Striking a stationary ball						
C1. Dominant hand grips bat above nondominant hand	87	98 (56)	0.015	94	95 (91)	0.673
C2. Nonpreferred side of body faces the imaginary tosser with feet parallel	72	0 (0)	N/A	87	2 (2)	<0.001[a]
C3. Hip and shoulder rotation during swing	66	32 (18)	<0.001[a]	81	50 (48)	<0.001[a]
C4. Transfers body weight to front foot	59	35 (20)	<0.001[a]	68	32 (31)	<0.001[a]
C5. Bat contacts ball	66	91 (52)	<0.001[a]	71	92 (88)	<0.001[a]
Stationary dribble						
C1. Contacts ball with one hand about belt level	60	12 (7)	<0.001[a]	85	9 (8)[b]	<0.001[a]
C2. Pushes ball with fingertips (not a slap)	62	51 (29)	0.084	82	70 (66)[b]	0.007[a]
C3. Ball contacts surface in front of or to the outside of foot on the preferred side	87	12 (7)	<0.001[a]	95	26 (24)[b]	<0.001[a]
C4. Maintains control of ball for four consecutive bounces without having to move feet to retrieve it	73	37 (21)	<0.001[a]	89	73 (68)[b]	<0.001[a]
Catch						
C1. Preparation phase where hands are in front of the body and elbows are flexed	89	77 (44)	0.004	96	54 (52)	<0.001[a]
C2. Arms extend while reaching for the ball as it arrives	88	63 (36)	<0.001[a]	94	78 (75)	<0.001[a]
C3. Ball is caught by hands only	60	33 (19	<0.001[a]	83	68 (65)	<0.001[a]
Kick						
C1. Rapid continuous approach to the ball	89	61 (35)	<0.001[a]	92	66 (63)	<0.001[a]
C2. An elongated stride or leap immediately prior to ball contact	41	37 (21)	0.523	71	63 (60)	0.066
C3. Nonkicking foot placed even with or slightly in back of ball	92	5 (3)	<0.001[a]	96	4 (4)	<0.001[a]
C4. Kicks ball with instep or preferred foot (shoelaces) or toe	91	58 (33)	<0.001[a]	95	79 (76)	<0.001[a]
Overhand throw						
C1. Windup is initiated with downward movement of hand/arm	69	14 (8)	<0.001[a]	79	24 (23)	<0.001[a]
C2. Rotates hips and shoulders to a point where the nonthrowing side faces the wall	57	14 (8)	<0.001[a]	73	7 (7)	<0.001[a]
C3. Weight is transferred by stepping with the foot opposite the throwing hand	66	25 (14)	<0.001[a]	76	48 (46)	<0.001[a]
C4. Follow-through beyond ball release diagonally across the body toward the nonpreferred side	69	60 (34)	0.127	84	58 (60)	<0.001[a]
Underhand roll						
C1. Preferred hand swings down and back, reaching behind the trunk while chest faces cones	85	2 (1)	<0.001[a]	90	2 (2)	<0.001[a]
C2. Strides forward with foot opposite the preferred hand toward the cones	58	5 (3)	<0.001[a]	74	20 (19)	<0.001[a]
C3. Bends knees to lower body	65	11 (6)	<0.001[a]	79	4 (4)	<0.001[a]
C4. Release ball close to the floor so ball does not bounce more than 4 inches high	60	7 (4)	<0.001[a]	66	2 (2)	<0.001[a]

FMS: fundamental movement skill; FMS mastery: possessing skill component during two trials; N/A: Not applicable as the prevalence of mastery for the overweight/obese sample = 0%.
[a]Significant difference between groups (P < 0.05).
[b]n = 94 due to missing data.