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The Relationships between Maturity and Functional Movement Screen Scores in School-Aged Girls and Boys

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Original Article

Abstract

Introduction: During the growth period, before and after maturity, considerable biological changes occur. It seems that these changes are related to neuromuscular patterns, and have significant differences in performing functional movements in young boys and girls during the maturation process. The purpose of this study was to examine the relationship between maturity and functional movement screen (FMS) scores in school-aged girls and boys.

Materials and Methods: The statistical sample included 700 school-aged, 9-18-year-old, boys and girls from Shahrekord City, Iran, categorized into 10 groups of 35 girls and 10 groups of 35 boys. To evaluate maturity and functional movement, the maturity offset prediction equations and FMS tests were used, respectively. To investigate the relationship between maturity and FMS scores the Spearman's rank correlation coefficient test was used ($P \leq 0.050$).

Results: Spearman correlation test showed a significant correlation between maturity offset and FMS scores ($r = 0.154$, $P < 0.001$). Moreover, there was a significant correlation between maturity offset and FMS scores in boys ($r = 0.334$, $P < 0.001$), but this correlation was not significant in girls ($r = -0.082$, $P > 0.050$).

Conclusion: There was a significant correlation between maturity and FMS scores in school-aged boys, but this correlation was not significant for girls. Therefore, realizing what changes may occur on the functional tests on the duration of the maturation process, can be considered as a goal for planning exercises; and some research can be done on the causes of these differences. Moreover, considering that functional tests may be affected by maturity, when interpreting these results, it is more accurate to consider biological age rather than chronological age.

Keywords: Puberty, Functional movement screen, School-aged children, Predicted maturity offset

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Introduction

Sports are gaining an increasing popularity among young people, in such a way that it is estimated that between 30 and 35 million American children aged 5-18 years annually participate in sports organized for them (1). In Iran, there are 14 million students in schools, all of whom attend physical education classes weekly (2). In addition, growth in some active adolescents is associated with an increase in acute and chronic injuries, and the injury rate in the lower limbs of high school athletes has been reported to be 1.33 per thousand hours of exercise (3). Puberty refers to an individual's level of maturity at a given point of time (4). Maturity status, skeletal age, adult height percentage, and chronological age are all indicators of the puberty state (4). The assessment of puberty state has specific uses, including helping to homogenize children to match competition, group students in exercises, equate chances of success for all, and reduce harm (5). Among individual of the same chronological age, especially regarding the adolescent growth mutation, there is a wide range of differences in physical and biological development (5).

Given the results of investigations, there are significant differences in neuromuscular patterns during functional movements between young girls

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and boys at puberty (6). One of the most important studies on youth and adolescent development is the identification of gender differences in development (7). Researchers have used strength and flexibility tests to measure the level of changes in motor performance in girls and boys, with most studies reporting differences in the strength and flexibility between girls and boys during development and maturity (7). According to the results of studies, the girls at the age of 13.5 to 14.5 years reach a strength level close to that of the adulthood (7). Moreover, it has been suggested that girls and boys have similar levels of power up to the age of 13 (7). Neuromuscular patterns in boys and girls change significantly during maturity, with boys exhibiting more neuromuscular changes during maturity compared to girls (6). Peak height velocity (PHV) is the most common method used as an indicator to predict puberty in longitudinal studies, providing a precise measure of maximum growth in adolescence and a common milestone for showing velocity of development in other body dimensions among the individuals in a group (7). Adult or mature players generally have larger physical dimensions and performances in comparison to their younger teammates who have newly reached maturity (8). In accordance with the findings of a study, there were large differences of 35 cm in height and 20% in performance in the sprint tests between the more or less mature players in the same age group (8). In adolescent exercise, chronological age is a common way of grouping children for exercises and competitions, but there may be differences in skeletal age by up to 4 years among people of the same age in an age group (5).

Motor function is a term often used to coordinate the various components of health-related fitness (muscle strength, muscle endurance, aerobic endurance, flexibility, and body composition) and movement-related fitness (speed, agility, coordination, balance, and power) (7). Motion assessments allow health and fitness professionals to identify motor deficiencies, muscle imbalances, and altered muscle use strategies (9). The results of investigations on motor function in children indicate that more than one third of children and adolescents tested did not have active lives that would increase their physical fitness (10). In recent years, the promotion of adult physical fitness has gained more attention, with little research being conducted on the fitness requirements of children. As a result, information on children’s physical fitness and their capacity to perform such activities is limited (10). There is also little information on the effects of puberty on the functional movement performance and mechanical changes in adolescents when performing these tests (11). When a coach has a proper understanding of the natural pattern of movement in young athletes, he/she can help them correct their motor deficits (12). Additionally, understanding how the performance tests will change with maturity can be considered as a goal for exercise planning.

Understanding the effects of growth and maturity on skills implementation is of great importance (11). Research results have shown that a lack of the age-related motor skills can be an obstacle to efficient movements or skills and can also be a barrier to learning complex motor patterns (4). Most of the body indices affecting functional tests such as strength and endurance tests increase after the peak adolescence development and puberty (11). Therefore, PHV is a period associated with the highest growth speed during puberty and can be suggested as a very useful reference for changes in physical dimensions (4). Although studies have shown that there may be a relationship between motor skills or performing efficient movements and injury prevention, the relationship between puberty and motor performance measures is somewhat unclear (13). Accordingly, the present study was carried out aiming to investigate the relationship between maturity and functional movement screen (FMS) scores among the school-aged male and female children.

Materials and Methods

This was a descriptive-correlational study performed to examine the relationship between puberty and FMS scores of the students. The statistical population consisted of all students of Shahrekord City, Iran, as 35 thousand children. The sample size was calculated to be 350 according to the population size using Cochran formula ($\alpha = 0.05$ and $1-\beta = 0.95$), and given the study goals and classification of the students, 700 school-aged boys and girls (9-18 years old) were selected on a randomized clustered basis and divided into 10 groups of 35 boys and 10 groups of 35 girls with no injury during the six months prior to the study (5). After specifying the target schools and classes, if there was only one class of a grade in each school, the same class was selected and if there were multiple classes of a grade, one class was randomly selected and all the class students participated in the tests. Prior to the start of the study, necessary permits were obtained from the authorities of the provincial education department and a consent form was received from the parents of the students and collected. Moreover, all stages of the study were approved by the ethics committee (code IR.UT.SPORT.REC.1398.012) of University of Tehran, Tehran, Iran, prior to commencement of the study.

The study exclusion criteria included any history of fracture or surgery in the lower limbs, history of musculoskeletal disorders (MSDs) such as low back pain (LBP), any pain or discomfort during tests, history of specific illnesses, use of any medication that could cause balance impairments or cognitive changes, and damage during the tests (5,11). First, the demographic information of the subjects including age, height, and weight were measured. Then, using verbal explanations, practical performances, and playing films, the necessary training on how to perform the tests was provided, followed by 2 minutes of dynamic warm-up including 2 minutes of slow running in different directions and 5 minutes of dynamic motivational exercises to enhance muscular activity in the upper and lower limbs (11).

The tests were conducted by two groups of physical education teachers including a 5-person group of men for boys' schools and a 5-person group of women for girls' schools. The examiners all had a M.Sc. degree and a Ph.D. degree in physical education with at least 8 years of experience. The training sessions provided information on how to perform the tests, how to score, and how to perform the measurements in a practical way by showing films to the project executives. To obtain the inter-rater reliability, 10 secondary-school male students in the ninth grade performed FMS maneuvers, and the examiners recorded the scores of each performance, with the intraclass correlation coefficient (ICC) obtained as 0.96 among the examiners' scores. On the test day, the students attended designated stations in the school gym and were provided with the necessary training and practice opportunities. Finally, without giving them any feedback, the FMS tests were conducted in a random order and recorded in special forms.

Maturity assessment: The predicted maturity offset formula was used to assess maturity (5). This formula was first developed by Mirwald et al. (Relation 1) (4) and has recently been updated by Koziel and Malina (Relation 2) (5). The original formula contains demographic information including standing height, sitting height, leg length, age, weight, and constant numbers, but in the new formula only the subjects' height and age values are applied to obtain the maturity prediction index (5). To gain certainty, both methods were calculated by the researchers and there was no difference between the results ($P \geq 0.050$). In the present study, the new formula was utilized to predict puberty.

Relation 1

Girls:

Maturity offset (years) = -9.376 + (0.0001882 × (leg length × sitting height)) + (0.0022 × (age × leg length)) + (0.005841 × (age × sitting height)) – (0.002658 × (age × mass)) + (0.07693 × (mass by stature ratio × 100));

Boys:

Maturity offset (years) = -9.236 + (0.0002708 × (leg length × sitting height)) + (-0.001663 × (age × leg length)) + (0.007216 × (age × sitting height)) + (0.02292 × (mass by stature ratio × 100)).

Relation 2

Girls:

Maturity offset (years) = -7.709133 + (0.0042232 × (age × stature))

Boys:

Maturity offset (years) = -7.999994 + (0.0036124 × (age × stature))

The number obtained from the formula based on individual's age and height takes positive or negative values (ranging from -4 to +4). This number is considered as a predictor of maturity indicating the time before or after reaching PHV.

The PHV age can be predicted given the number obtained from the maturity prediction formula and the chronological age. For example, if the number obtained from the formula for an 8-year-old person is -3.5, the person has not yet reached their PHV age and is in the pre-PHV stage, and if this number is summed up with the chronological age (8 years) ignoring the negative sign, 11.5 years will be obtained, indicating that the person has reached their PHV peak at the age of 11.5 years. If this index is +3 for a 17-year-old, it means that the person has reached the PHV age at the age of 14 and is in their post-PHV stage.

Functional movement evaluation: To evaluate motor performance, the FMS test set consisting of 7 tests of "deep squat, hurdle step, inline lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability" were used, with a high reliability reported (0.98) (14). Each movement pattern was performed three times by the subjects and the score of each test was inserted in the special table in the range of 3-1, indicating perfect execution of the movement pattern, complete execution of the movement pattern with compensatory movements, and incomplete execution of the movement pattern, respectively, and the total score of the seven tests was calculated for each person (15).

The Kolmogorov-Smirnov (K-S) test was utilized to check the normal distribution of the data. Since the data were not normally distributed ($P \geq 0.050$), the Spearman correlation test was exploited to investigate the relationship between maturity and scores of the FMS tests. Finally, the data were analyzed in SPSS software (version 24, IBM Corporation, Armonk, NY, USA). $P \leq 0.05$ was considered as the significance level.

Results

The demographic information of the participants by age group is presented in table 1, in addition to the information on the FMS maturity prediction index and the FMS scores presented in table 2. Given the Spearman test results, there was a significant correlation between the maturity prediction index and FMS scores (r = 0.154, P < 0.001). Moreover, there was a significant correlation between the maturity prediction index and FMS scores in boys (r = 0.334, P < 0.001), however this correlation was not significant in girls (r = -0.082, P > 0.050).

Table 3 illustrates the correlation between the maturity prediction index and the FMS scores for each age group. Furthermore, the relationship between the maturity prediction index and the age groups by sex is indicated in figure 1, with the relationship between the scores of the FMS tests in different age groups by sex demonstrated in figure 2.

Based on the findings, on average, the FMS test scores of the students aged 9-18 years were higher than 14 (Figure 2). Besides, the mean FMS scores in all age groups, in line with the increase in the predicted maturity offset from -4 to +4, increased by 2 and reached from 14.11 to 16.10 (Table 2).

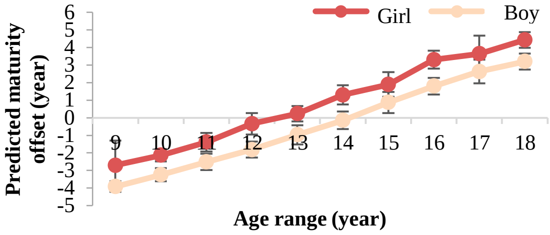

Figure 1. Relationship between predicted maturity offset and age range by gender

Discussion

The present study was accomplished with the objective to investigate the relationship between puberty and FMS scores of the school-aged girls and boys. The results revealed a significant correlation between the predicted maturity offset and FMS scores. In addition, there was a significant correlation between the predicted maturity offset and FMS scores in boys, however this correlation was not significant for girls.

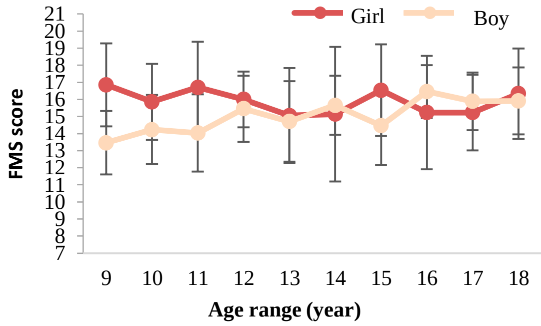

Figure 2. Relationship between functional movement screen (FMS) scores in different age ranges by gender

Table 1. Demographic information of participants by age

Age (year)	Length (cm)			Weight (kg)			Predicted maturity offset (year)		
	Female	Male	Total	Female	Male	Total	Female	Male	Total
< 9	131.97 ± 5.99	133.69 ± 5.06	133.00 ± 5.61	27.89 ± 7.64	25.96 ± 3.990	27.00 ± 6.13	-2.71 ± 1.41	-3.92 ± 0.30	-3.31 ± 1.18
< 10	138.12 ± 5.72	138.00 ± 6.41	137.87 ± 6.05	31.49 ± 8.41	31.14 ± 7.74	31.33 ± 8.12	02.13 ± 0.36	-3.24 ± 0.37	-2.63 ± 0.37
< 11	143.47 ± 8.09	143.97 ± 4.69	143.31 ± 6.61	37.51 ± 9.80	36.43 ± 10.73	36.97 ± 10.29	-1.39 ± 0.53	-2.51 ± 0.47	-1.95 ± 0.76
< 12	150.31 ± 7.83	148.97 ± 6.09	149.64 ± 7.04	38.60 ± 9.61	36.71 ± 8.81	37.67 ± 9.27	-0.34 ± 0.61	-1.81 ± 0.45	-1.07 ± 0.91
< 13	152.97 ± 5.36	158.87 ± 8.90	154.91 ± 7.60	43.37 ± 8.74	50.10 ± 15.40	46.74 ± 12.96	0.23 ± 0.43	-0.97 ± 0.54	-0.34 ± 0.75
< 14	156.57 ± 7.70	162.17 ± 7.00	159.37 ± 7.89	53.40 ± 13.99	51.89 ± 11.47	52.64 ± 12.81	1.30 ± 0.55	-0.15 ± 0.50	0.58 ± 0.89
< 15	157.31 ± 10.81	166.43 ± 7.47	161.87 ± 10.45	55.71 ± 17.35	58.60 ± 15.20	57.17 ± 16.37	1.89 ± 0.70	0.87 ± 0.60	1.38 ± 0.83
< 16	166.71 ± 4.82	173.23 ± 5.14	170.00 ± 5.94	60.47 ± 13.17	63.03 ± 13.76	61.57 ± 13.55	3.30 ± 0.51	1.80 ± 0.47	2.55 ± 0.89
< 17	167.83 ± 6.19	176.97 ± 6.60	171.37 ± 8.47	58.97 ± 11.35	66.20 ± 12.91	62.59 ± 12.59	3.64 ± 1.03	2.63 ± 0.67	3.13 ± 1.01
< 18	165.29 ± 5.19	177.29 ± 5.80	171.29 ± 8.13	57.51 ± 10.19	68.83 ± 14.16	63.17 ± 13.57	4.43 ± 0.45	3.20 ± 0.46	3.82 ± 0.72

Data were reported as mean ± standard deviation (SD).

Table 2. Information on the predicted maturity offset and functional movement screen (FMS) scores

Predicted maturity offset (year)	Number			Total FMS score		
	Female	Male	Total	Female	Male	Total
-4	0	19	19	0	14.11 ± 1.33	14.11 ± 1.33
-3	17	44	61	16.06 ± 2.46	13.57 ± 2.09	14.26 ± 2.46
-2	47	54	101	17.06 ± 2.20	14.72 ± 2.16	15.81 ± 2.47
-1	38	42	80	15.95 ± 2.62	15.07 ± 2.28	15.49 ± 2.48
0	41	39	80	15.63 ± 2.43	15.00 ± 2.14	15.33 ± 2.32
1	43	37	80	15.51 ± 2.03	15.35 ± 2.09	15.44 ± 2.06
2	44	29	73	16.30 ± 2.94	15.45 ± 1.68	15.96 ± 2.54
3	25	55	80	15.84 ± 3.01	15.85 ± 2.18	15.85 ± 2.54
4	56	28	84	15.30 ± 2.74	15.89 ± 1.98	15.50 ± 2.54
5	39	3	42	16.10 ± 2.80	16.00 ± 1.41	16.10 ± 2.76

FMS: Functional Movement Screen
Data were reported as mean ± SD.

Maturity assessment has many applications, including the classification of children with the aim of homogenizing them to participate in sports and reduce injury among them (16). Puberty refers to an individual's level of maturity at a given point in time (4). Skeletal age, adulthood height, and chronological age are indicators of the puberty state (7). In the past, there were various methods, such as radiology imaging, clinical evaluations, and secondary sex characteristics to predict puberty that were expensive and invasive (12). Recently, the puberty prediction method has been proposed by measuring the chronological age, weight, height, and sitting height, lacking the limitations of the previous methods. This formula provides an accurate measure of maximum growth in adolescence and is a common milestone to show the growth rate of other physical dimensions among individuals in a group (7). Therefore, PHV is a period with the highest growth speed during maturity and would be very useful if considered as a reference for changes in physical dimensions (4). Many researchers have suggested that performance of the youth in power and strength development begins about 1.5 years prior to PHV and reaches the peak level approximately one year after PHV, while a period of acceleration in speed performance occurs before PHV (17). However, a lack of the experimental knowledge about the effects and optimization of exercises during growth and puberty has led to controversy in this regard.

The results of the current study showed that there was a significant relationship between the predicted maturity offset and FMS scores, i.e. the students with higher predicted maturity offset had better FMS scores. The results of investigations have indicated that some functional tests are temporarily affected by puberty in the youth homogenized by age (18). Thus, more mature individuals in similar tests performed better than their less mature counterparts (18). Therefore, when interpreting these results, one should consider the puberty state and the biological age rather than the chronological age (7). These findings are in agreement with the results of the study by Yildiz on the relationship between maturity and athletic performance in children (19). The results of a study suggested that biological maturity affects physical performance and these effects are mainly due to changes in hormone levels, increased muscle mass, increased speed of nerve impulses, and increased muscle coordination, all of which leading to the development of physiological and physical variables (20). The FMS tests are designed primarily to evaluate muscle flexibility, strength imbalance, and quality of movement and to identify deficits in the proprioception function, mobility, and stability in the joints while performing movement patterns (21). Some studies have examined the FMS scores on students (18,22). In a study, Wright et al. reported the low scores of students in the FMS tests (22). However, information on the relationship between maturity and performance of the adolescents in FMS is limited and the investigations tend to be focused on this relationship.

Table 3. Information on correlation between predicted maturity offset and Functional Movement Screen (FMS) scores for age groups by sex

		Predicted maturity offset									
Age (year)		< 9	< 10	< 11	< 12	< 13	< 14	< 15	< 16	< 17	< 18
FMS	Female	0.009	-0.304	-0.272	0.026	0.060	-0.266	0.286	-0.159	0.234	-0.251
	Male	-0.348*	0.080	-0.044	-0.074	-0.337*	-0.016	-0.178	-0.069	0.076	-0.190

FMS: Functional Movement Screen
P< 0.050 was considered as the significance level.

The control of the puberty effects in the adolescence seems necessary to classify young athletes into homogeneous groups and to conduct further studies (4).

In accordance with the results of the current study, there was a significant correlation between the predicted maturity offset and the FMS scores in boys, while this correlation was not significant for girls. One of the most important areas of studies on the youth and adolescent development is the identification of developmental differences considering gender (23). In a study carried out by Figueiredo et al., the differences in the mean height and weight of the players in a similar age range with minimum and maximum maturity were 15 cm in height, 21 kg in weight, and 3.7 years in skeletal age, respectively (23). Researchers also used functional strength and flexibility tests to measure changes in the functional movement performance between girls and boys (7), with most studies reporting differences in the strength and flexibility between girls and boys during the development and adolescence stages (7). Investigations have shown that girls and boys have similar levels of power up to the age of 7 years old (7). Neuromuscular patterns in girls and boys change significantly during adolescence, with boys exhibiting more neuromuscular changes during adolescence compared to girls (7). Moreover, with the increase in maturity, there is an increase in the strength, power, and coordination in boys, while on average girls exhibit fewer changes during maturity (24).

The FMS tests are now widely used in studies (9). The maximum score an individual can gain on these tests is 21. On the basis of the previous studies, the individuals with a score of 14 or less on this test are at high risk of injury (25). The results of the current study showed that the mean scores of the FMS tests were higher than 14 for the 9-18 year-old students, and this finding could indicate a lower risk of injury in the students (Figure 2). Additionally, based on the findings in the present study, the mean FMS scores in all age groups, along with the increase in the predicted maturity offset from -4 to +4, increased by 2 and reached from 14.11 to 16.10 (Table 1). Since the puberty stages are associated with the occurrence and type of sports injury, assessing gender differences in neuromuscular performance during development and puberty can help identify risk factors leading to differences in the injury rates between the genders and play an important role in developing the injury prevention strategies (6).

Limitations

Limitations of the present study include lack of control over the level of activity of the students, whether they were athletes or non-athletes, as well as lack of evaluation of other fitness indicators and their relationship with adolescence.

Recommendations

Further studies are recommended to be conducted to measure the long-term effect of exercise interventions on maturity and FMS scores. It is also suggested to examine the maturity status and the prevalence rate of injuries.

Conclusion

Given the results of this study, there was a significant correlation between the predicted maturity offset and FMS scores among the students. In addition, there was a significant correlation between the predicted maturity offset and FMS scores in boys, however this correlation was not significant for girls. Therefore, understanding the changes in functional movement tests with maturity can be considered as a goal for exercise planning, and studies can be conducted to identify and examine the causes of these differences. Moreover, taking into account the fact that the functional movement tests may be affected by puberty, it is suggested that the biological age be used rather than the chronological age when interpreting the results of these tests.

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Authors' Contribution

Khodayar Ghasempour: Design and ideation of the study, attracting funding for the study, supporting and performing executional and scientific services of the study, providing study equipment and samples, collecting information, manuscript arrangement, final verification of the manuscript for submission to the journal office, responsibility for preserving the integrity of the study process from beginning to publication, and responding to referees; Mohammad Hossein Alizadeh: study design and ideation, supporting and performing executional and scientific services of the study, providing study equipment and samples, analysis and interpretation of results, specialized statistics services, manuscript arrangement, manuscript expert evaluation in terms of scientific concepts, final manuscript approval for submission to the journal office, responsibility for maintaining the integrity of the study from beginning to publication and responding to the comments of the referees, Hooman Minoonejad, study design and ideation, supporting and performing executional and scientific services of the study, analysis and interpretation of results, specialized statistical services, manuscript arrangement, manuscript expert evaluation in scientific terms, final manuscript approval for submission to the journal office, responsibility for maintaining the study integrity from beginning to publication, and responding to the comments of the reviewers, Mahdieh Akoochakian, study design and ideation, supporting and performing executional and scientific services of the study, providing study equipment and samples, analysis and interpretation of results, manuscript arrangement, manuscript expert evaluation in terms of scientific concepts, final manuscript approval for submission to the journal office, responsibility for maintaining the integrity of the study from beginning to publication and responding to the comments of the referees.

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Conflict of Interests

The authors declare no conflict of interest.

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