Title: Maturational effect on Functional Movement Screen™ score in adolescent soccer players
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Abstract

Objectives The effect of maturity on Functional Movement Screen (FMS) scores in elite, adolescent soccer players was examined. **Design** A cross-sectional observational study was completed. **Methods** Participants were 1163 male English Football League soccer players (age 8 – 18 years). . Players were Mid-Foundation Phase (MF) (U9); Late Foundation Phase (LF) (U10 and U11); Early Youth Development Phase (EYD) (U12 and U13); Mid-Youth Development (MYD) Phase (U14 to U15); Late Youth Development Phase (LYD) (U16) and Early Professional Development Phase (EPD) (U18). Age from peak height velocity was estimated and players were categorized as pre- or post- peak height velocity (PHV). To analyse where differences in FMS_{total} score existed we separated the screen into FMS_{move} (3 movement tests); FMS_{flex} (2 mobility tests) and FMS_{stab} (2 stability tests). **Results** FMS_{total} median score ranged from 11 at MF to 14 for EPD. There was a substantial increase (10%) in those able to achieve a score of ≥14 on FMS_{total} in those who were post-PHV compared to pre-PHV. This was explained by a substantial increase in those achieving a score of ≥4 on FMS_{stab} (21%). There was a substantial increase in the proportion of players who achieved the FMS_{total} threshold of ≥14 with an increase of 47.5 (41.4 to 53.6) % from the MF phase to the EPD phase due to improvements in FMS_{move} and FMS_{stab}. **Conclusions** PHV and maturity have substantial effects on FMS performance. FMS assessment appears to be invalid for very young players. Findings are relevant to those analyzing movement in soccer players.

Keywords: adolescence; football; movement; athletic performance

Introduction

Physical assessments of adolescents are useful because they can discriminate between elite and sub-elite performance[1,2] and are used to inform an adolescent's performance level and future potential.[3] During adolescence individuals experience skeletal, neuroendocrine and sexual maturation developments that make the assessment of physical performance and training prescription of young athletes a complex process.[4] Each individual's timing and tempo for maturation varies, meaning adolescents have unique biological ages.[4] Some performance tests are transiently affected by maturity in age-matched adolescents, whereby more mature individuals perform better on the same test versus their less mature counterparts.[3,5] Therefore, when interpreting these results it is appropriate to consider an individual's maturity status and consider them in relation to biological age as opposed to chronological age.[4] Failure to do this results in talent selection being biased towards the early maturers.[4,6] Some physical performance measures, though, are not influenced by maturity status of the adolescents.[7] Hence, to fully evaluate the results of a performance test in relation to talent identification and development completed by adolescents it is essential to establish whether a test is biased by the maturity status. Mirwald et al.[8] proposed a non-invasive method for estimating somatic maturity using chronological age, stature, sitting height and body mass, which can be used to dichotomize samples into pre- and post-peak height velocity. Many of the physical characteristics that influence performance tests, such as strength and endurance, are increased after the peak adolescent growth spurt.[5] Therefore, peak height velocity, the period of most accelerated growth during puberty, was suggested as a useful reference for changes in body dimensions and physical proportions.[9]

Within contemporary testing batteries the assessment of neuromuscular control and kinematics are included to measure movement competencies and limitations. The Functional Movement Screen™ (FMS)[10] is one such test that is widely used to assess these qualities in physically active populations. The FMS is a reliable tool for intra-[11,12] and inter-rater[13,14] agreement (weighted Kappa 0.8 – 1.0) that consists of a series of seven tests to assess and grade fundamental movements, mobility and stability.

The screen is valid for predicting injury potential in adult populations, whereby those scoring lower on the test (<=14) are at increased odds of incurring musculoskeletal injuries.[15-17] However, data on the performance of adolescents on the FMS is sparse and has tended to focus on relationships between FMS and performance measures.[18] There is one small study that describes the effect of maturity on FMS performance.[19] This study, however, only included 30 participants and as such was limited to providing data for a small number of participants in just three adolescent age group categories. Therefore, the aim of this study was to demonstrate FMS scores in relation to maturity and to examine the effect of maturity on FMS scores in elite, adolescent soccer players.

Methods

Participants were 1163 junior, male soccer players (age 8 – 18 years) from nineteen English Football League clubs (Table 1). The players represented clubs within the English Elite Player Performance Plan (EPPP) system, (Category 2: 1 club, Category 3: 16 clubs and Category 4: 2 clubs). All players were free from injury and medically cleared to participate in training. Ethics approval was obtained from the University ethics committee, and written informed consent was obtained from the parents or guardians of the participants.

Players were tested in the chronological age group in which they play. Age groups were divided by 1-year intervals from under 9 years (U9) to under 16 years (U16). The players aged 17 and 18 years play and train together and so were grouped together. The EPPP, the system in which these players are developed, categorizes adolescent players into Foundation Phase (U5 to U11 years), Youth Development Phase (U12 to U16 years) and the Professional Development Phase (U17 to U21 years).[20] To reflect EPPP categories, whilst also enabling the analysis of the effect of maturity we placed players into six categories; Mid-Foundation Phase (MF) (U9); Late Foundation Phase (LF) (U10 and U11); Early Youth Development Phase (EYD) (U12 and U13); Mid-Youth Development (MYD) Phase (U14 to U15); Late Youth Development Phase (LYD) (U16) and Early Professional Development Phase

(EPD) (U18).

Age from peak height velocity was estimated using a non-invasive practical method[8] and players were categorized as pre- or post- peak height velocity (Table 1). The MYD phase was the development phase where there was the biggest mix of pre-PHV (N = 135) and post-PHV (N = 128). This age category was used to investigate the effect of PHV on FMS score (shaded in table 3). Data were presented for both pre- and post- PHV. Those players who experienced early PHV (EYD: N = 3) or late PHV (LYD: N = 3) were excluded from the analysis (Table 1). Therefore, in all other phases players were all pre-PHV (MF, LF, EYD) or post-PHV (LYD, EPD).

Players reported to their regular training venue at the end of the pre-season period and were provided with instructions of the testing procedure. The FMS was implemented in accordance with the manufacturer's user manual using the bespoke FMS equipment.[10] The players were familiarized with the movements required prior to the recorded testing. Players were assessed on the FMS by a trained practitioner with 5 years' experience of recording FMS performance who assessed all exercises of the screen.

As per the official guidelines[10] the tests of the FMS included; overhead squat, hurdle step, inline lunge, shoulder mobility, active straight leg raise, trunk stability push up and rotary stability and tests were completed in this order. All players were injury-free and therefore passed the FMS clearing screens, where appropriate. Players were awarded a score of 0-3 for each test and then a total score between 0 to 21; the sum of all seven tests (FMS_{total}). A 3 score was indicative of completing the movement perfectly and pain-free. A 2 score was awarded when the movement was performed pain-free but with minor compensatory patterns and is considered 'satisfactory'. A 1 score indicated the movement could not be completed as instructed and a 0 was given when pain was reported whilst performing the movement. Where a test was completed on left and right side the lesser of the two scores for that test was assigned to contribute to FMS_{total}. To enable a deeper understanding of where differences in FMS_{total} score existed between groups we separated the screen into 3 parts: FMS_{move} (3 movement tests; overhead squat, hurdle step, inline lunge); FMS_{flex} (2 mobility tests; shoulder mobility, active straight leg raise,) and FMS_{stab} (2 stability tests; trunk stability push up, rotary stability).

The FMS scores in each age group were summarized using the median and interquartile range. In each development phase, we derived the proportion of players achieving a score ≥14 for FMS_{total}, ≥6 for FMS_{move}, and ≥4 for FMS_{flex} and FMS_{stab}, respectively. These cut-points are equivalent to scoring a '2' on each test - 'satisfactory' performance. A score of 2 on each test would ensure a total score of 14, which has been shown to be the cut-point for reduced injury risk in adults.[15-17] We calculated differences in proportions as the proportion in the subsequent development phase minus that in the prior phase. Differences between proportions are presented with 90% confidence intervals.[21] We elect not to adjust for multiple comparisons.[22] Analysis was conducted using Stata® software (StataCorp. 2013. *Stata Statistical Software: Release 13*. College Station, TX: StataCorp LP).

Results

The median (interquartile range) for FMS_{total}, FMS_{move}, FMS_{flex} and FMS_{stab} for the players within their chronological age groups are presented (Table 2). With the exception of FMS_{flex} there was a trend for the median score to increase as the players matured from U9 to U18. FMS_{total} median score ranged from 11 at U9, where 75% of the participants scored 11.5 or less, to 14 for U18, where 75% of participants scored 15 or less.

Across the entire period of adolescence (MF to EPD) the proportion of players achieving the threshold score for FMS_{total}, FMS_{move}, FMS_{flex} and FMS_{stab} for each development phase are reported in Table 3. There was a substantial increase in the proportion of players who were able to achieve the FMS_{total} threshold of ≥14 with an increase of 47.5 (95% CI: 41.4 to 53.6) % from the MF phase to the EPD phase. The increase in total score was further explained by substantial increases in the proportion of players who achieved the threshold score in both FMS_{move} (39.1; 31.2 to 47.0%) and FMS_{stab} (70.4; 63.1 to 76.0%). While FMS_{flex} only changed by 1.7 (-6.8 to 10.2) % from MF to EPD it increased substantially (10.5%) prior to puberty (MYD pre- PHV vs. EYD) before reducing again post- PHV at the LYD phase.

No players were able to achieve the FMS_{stab} threshold at LF, whilst only small proportions of the other pre-PHV groups could achieve the threshold (3.9% and 15% respectively). While FMS_{stab} showed an initial substantial increase from LF to EYD (11%) the biggest, most substantial, increase in the proportion of those players achieving the threshold score occurred post-PHV with an additional 54% able to achieve the threshold in EPD compared to MYD (pre- PHV). For FMS_{move} a substantial increase (22.2%) occurred pre-PHV (LF to EYD). A further 21% of players were able to meet the FMS_{move} post-PHV between to MYD (pre-PHV) to EPD with small increases at each development phase.

The effect of PHV on FMS scores is presented in the shaded MYD phase (Table 3). There was a substantial increase in those able to achieve a score of ≥14 on FMS_{total} from those in the MYD phase who were pre-PHV compared to those participants who were post-PHV. This improvement in total score can be explained largely by a substantial increase in achieving a score of ≥4 on FMS_{stab} (21%) from pre- PHV to post- PHV. The changes in FMS_{move} and FMS_{flex} in this stage are less clear, and explain less of the improvement in FMS_{total}.

Discussion

Our study aimed to examine the effect of maturity on FMS scores in elite, adolescent soccer players. We demonstrated that the ability for players to achieve a satisfactory score for FMS_{total}, FMS_{move}, and FMS_{stab} increased substantially during adolescence. We showed PHV, as identified by a player being pre- or post- PHV during the MYD phase, had a substantial effect on the proportion of players able to achieve the FMS_{total} threshold score, consolidating preliminary work by Lloyd et al.[19]. We demonstrated that this observation was likely explained by the substantial increase of those able to achieve the FMS_{stab} threshold post-PHV. Regardless of why more players could achieve the threshold score it appears crucial to establish a player's PHV status when using the FMS to identify functional movement characteristics in young players. This would be particularly relevant within the MYD phase (U14/U15) when most of the players experienced PHV.

Whilst increased training volume in the older players may account for some of the increases in proportions achieving the threshold scores in FMS_{total} and FMS_{stab} it doesn't account for all. This is particularly pertinent in the MYD phase where training volumes were equal but there was a substantial increase in the more mature players able to achieve ≥14 for FMS_{total} and ≥4 for FMS_{stab}. The FMS_{stab} tests, particularly the trunk stability push up requires upper body strength. To achieve a score of 3 on this test the hands are placed next to the forehead while the body is in prone position before the player performs a push-up, raising their entire torso to finish with straight arms, balanced only on their hands and feet.[10] Hormonal and growth related changes from puberty associated with the Post-PHV stage mean that male players benefit from increased muscle mass and strength.[23] Increased strength may explain why a much greater proportion of post-PHV players can complete the FMS_{stab} tests above the threshold of ≥4 compared to those players pre-PHV. Strength continues to increase in males throughout adolescence and peak muscle mass occurs between the ages of 18-25 years.[23] This helps to explain further why the proportion of players able to achieve the FMS_{stab} threshold continues to increase substantially post-PHV in both the LYD and EPD groups, respectively. It is likely the push up is a test of strength for the young adolescence rather than a test of stability.

Despite being Pre-PHV a small, but substantially higher, proportion of the players in the EYD stage (compared to the LF and MF phases) achieved the threshold score for FMS_{stab}. It is theorized that a pre-pubertal 'window of opportunity' exists around the age of 11 years, relating to enhancements in neuromuscular efficiency as a result of improvements in motor coordination.[24] These improvements result from full maturity of the nervous system in the early stages of adolescence.[25] Neuromuscular efficiency, coordination, firing and skill learning are all known to develop due to these effects.[26,27] Therefore, the EYD players could have benefitted from strength increases caused from the maturity of the nervous system that enabled substantial increases in the proportion able to achieve the FMS_{stab} threshold compared to the LF stage. These data in particular call into question the validity of the use of FMS_{stab} tests for the foundation stage age groups. Practitioners should only consider using the FMS_{stab} as a test from the youth development phase onwards where more of the players may benefit from nervous system maturity that appears to improve their ability to perform the FMS_{stab} tests.

While FMS_{flex} and FMS_{move} do not change substantially in the proportion of those able to achieve threshold scores due to change in PHV, they increase substantially prior to the MYD phase. The FMS_{move} proportion increased substantially by 22% between EF and EYD. The theoretical maturity of the nervous system may also explain improvements in FMS_{move} as it does improvement of FMS_{stab} at this stage.[25] FMS_{flex} proportions increased substantially between EYD and MYD (pre-PHV), in the phase immediately prior to the players experiencing puberty. Post-PHV, the proportion of players achieving the FMS_{flex} threshold declines to similar values seen in the MF phase. Previous research has suggested that adolescent growth has no effect on flexibility of the lumbar and hamstring regions.[28] Previous work has not demonstrated the substantial increases and decreases in flexibility around PHV as we have demonstrated. A limitation of our data is that it is not longitudinal and we did not track the same individuals throughout their adolescence. It would be of interest to consider flexibility of individuals as they progress through adolescence to see if we observe this increase and decrease of FMS_{flex} around PHV in individuals over the time-course of their maturity.

Previous studies identified a score of ≤14 on the FMS_{total} were associated with an increased injury risk in adults.[15-17] The median FMS_{total} score is below this cut-point score of 14 for all phases apart from EPD. Firstly, because less than 75% of the players can achieve a score of 14 up to the LYD phase our data suggest that use of the ≤14 score cut-point for identification of injury risk may not to be applicable to adolescent soccer players. Further work could identify an appropriate cut-point for increased injury risk in young players. We did no analysis of bilateral asymmetries within the FMS in the current study. In previous work asymmetries in the tests in the FMS where a score for both left and right side are made has also shown to lead to increased injury risk in adult populations.[29] It would therefore be useful for further work to identify asymmetries in these FMS scores.

In professional NFL players the mean FMS_{total} score was 16.9 (SD 3.0)[16] and in military officer candidates, aged 18-30, the mean score was 16.6 (SD 1.7).[17] In our study the observation that despite approaching adulthood, only 5 in 10 of the EPD group were able to achieve a score of ≥14 may be an indication of relatively poor functional movement scores in this population and further improvements are needed to reduce risk of injury in these players when they reach adulthood. Over 70% of players at EPD are able to achieve the threshold scores for both FMS_{flex} and FMS_{stab} but the FMS_{move} is at just over 50%. This suggests that players at this stage may require more focus on the movement skills and converting their strength and flexibility into better quality fundamental movement skills whereas at earlier phases stability as well as movement appears to require a greater focus. Targeted neuromuscular training has been shown to improve movement and reduce injury risk of key musculoskeletal injury in young athletic populations.[30] It could therefore be useful for soccer players to include such training during adolescence to increase the proportion of players able to achieve the threshold score of 14 by the

EPD stage and beyond into adulthood. This intervention could be complimented with training that develops hypertrophic changes in post-PHV players to create improvements in fundamental functional movement. Future research could measure the effect of long term integrated training interventions on FMS score.

Conclusion

Maturity during the entirety of adolescence had substantial effects on the proportion of players who were able to achieve the threshold score on the FMS_{total}. This finding was due to substantial changes in both FMS_{move} and FMS_{stab}. Being post-PHV had a substantial effect on FMS_{total} compared to MYD counterparts who were pre-PHV. This was explained by a substantial increase in the proportion of players able to achieve the FMS_{stab} threshold score. Coaches should ensure they evaluate movement competency of junior players in context of the player's maturity status and particularly whether they are pre or post PHV.

Practical Implications

- A substantially greater proportion of players post-PHV were able to achieve 'satisfactory' movement meaning the maturity of the players should be accounted for to further contextualize results of FMS testing.
- Stability tests of the FMS, in particular, demonstrate a substantial effect of maturity. This observation seems to be explained by the strength requirements of the stability tests. Seeking a stability test with a lesser strength demand might be more appropriate for the younger players. Alternatively, removal of these tests with a revision of the overall threshold score could be an option for the younger players.
- The FMS may not be a valid movement measurement tool for young adolescents (under 11 years) because it does not discriminate good and poor movement. A more age-appropriate

movement screen may be beneficial.

- The FMS scores of those at the end of adolescence are low with only 50% of the players able to achieve the threshold for 'satisfactory'. This may expose this group to increased injury risk as young adults and players may benefit from neuromuscular training to improve the FMS score.

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Conflict of Interest

There are no conflicts of interest in the present study and the study was not funded by any external bodies

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Table 1: Descriptive data for the study participants

	MF	LF		EYD		MYD		LYD	EPD
Age category	**U9**	**U10**	**U11**	**U12**	**U13**	**U14**	**U15**	**U16**	**U18**
N	90	103	116	111	109	135	128	121	250
Height (m)	132.7	136.9	142.5	148.6	154.7	162.4	171.6	175.9	179.0
(SD)	(5.6)	(5.8)	(6.1)	(6.4)	(7.1)	(8.4)	(7.0)	(6.4)	(6.3)
Weight (kg)	29.3	32.4	36.1	39.3	44.3	50.2	61.3	66.3	72.48
(SD)	(4.2)	(4.4)	(5.4)	(5.2)	(7.3)	(8.4)	(12.7)	(7.6)	(6.9)
Pre PHV (n)	90	103	115	111	106	112	24	3*	0
Post PHV (n)	0	0	0	0	3*	23	104	118	250
Training hours per week (approx.)	3	3	3	6	6	6	6	12	12

MF = mid-foundation phase; LF = late foundation phase; EYD = early youth development phase; MYD = mid-youth development phase; LYD = late youth development phase; EPD = early professional development phase; PHV = peak height velocity

* players treated as outliers and removed from further analysis

Table 2: Median [interquartile range] FMS scores by age-group

	MF	**LF**		**EYD**		**MYD**		**LYD**	**EPD**
Age group	**U9**	**U10**	**U11**	**U12**	**U13**	**U14**	**U15**	**U16**	**U18**
FMS_{total}	11 (9.5 to 11.5)	11 (9.75 to 12)	11 (9 to 12)	11 (9.5 to 13)	12 (10 to 13)	12 (11 to 13)	13 (11 to 14)	13 (12 to 14.8)	14 (12 to 15)
FMS_{move}	4 (4 to 5)	4 (4 to 5)	5 (4 to 5.6)	5 (4 to 6)	5 (4 to 6)	5 (4 to 6)	5 (4 to 6)	5 (5 to 6)	6 (4 to 6)
FMS_{flex}	4 (3.5 to 4.5)	4 (3 to 5)	4 (3 to 5)	4 (3 to 5)	4 (3 to 5)	4 (4 to 5)	4 (4 to 5)	4 (4 to 5)	4 (4 to 5)
FMS_{stab}	2 (2 to 2.5)	2 (2 to 2.5)	2 (2 to 3)	3 (2 to 3)	3 (2 to 3)	3 (2 to 3)	3 (3 to 4)	4 (3 to 4)	4 (3 to 4)

MF = mid-foundation phase; LF = late foundation phase; EYD = early youth development phase; MYD = mid-youth development phase; LYD = late youth development phase; EPD = early professional development phase. FMS = functional movement screen; FMS_{total} = FMS total; FMS_{move} = FMS movement; FMS_{flex} = FMS flexibility; FMS_{stab} = FMS stability.

Table 3: Proportion of players in each development phase that achieved the cut-point for the FMS tests. The difference shown (90% confidence interval) is the proportion in the subsequent development phase minus that in the prior phase.

	FMS_{total} (≥14)	**FMS_{move} (≥6)**	**FMS_{flex} (≥4)**	**FMS_{stab} (≥4)**
MF (pre-PHV) N = 90	3.3%	13.3%	76.7%	0%
LF (pre-PHV) N = 219	20.7% 17.4 (11.9 to 22.9) %	8.7% -4.6 (-11.3 to 2.1) %	70.6% -6.1 (-15.0 to 2.8) %	3.9% 3.9 (0.5 to 7.3) %
EYD (pre-PHV) N = 217	16.8% -3.9 (-10.0 to 2.2) %	30.9% 22.2 (16.2 to 28.2) %	70.0% -0.6 (-7.8 to 6.6) %	15.0% 11.1 (6.6 to 15.6) %
MYD (pre-PHV) N = 135	23.6% 6.8 (-0.5 to 14.1) %	31.9% 1.0 (-7.4 to 9.4) %	80.5% 10.5 (2.9 to 18.1) %	16.6% 1.6 (-5.0 to 8.2) %
MYD (post-PHV) N = 128	33.6% 10.0 (0.9 to 19.1) %	37.3% 5.4 (-4.2 to 15.0) %	82.3% 1.8 (-6.1 to 9.7) %	37.5% 20.9 (12.1 to 29.7) %
LYD (post-PHV) N = 118	48.3% 14.7 (4.5 to 24.9) %	45.8% 8.5 % (-1.8 to 18.8)	76.3% -6.0 (-14.5 to 2.5) %	58.5% 21.0 (10.7 to 31.3) %
EPD (post-PHV) N = 250	50.8% 2.5 (-6.7 to 11.7) %	52.4% 6.6 (-2.6 to 15.8) %	78.4% 2.1 (-5.6 to 9.8) %	70.4% 11.9 (3.1 to 20.7) %

MF = mid-foundation phase; LF = late foundation phase; EYD = early youth development phase; MYD = mid-youth development phase; LYD = late youth development phase; EPD = early professional development phase. PHV = peak height velocity. Shaded area = pre- vs. post-PHV in the MYD phase. FMS = functional movement screen; FMS_{total} = FMS total; FMS_{move} = FMS movement; FMS_{flex} = FMS flexibility; FMS_{stab} = FMS stability.