

Differences in Lower Extremity Movement Quality by Level of Sport Specialization in Cadets Entering a United States Service Academy

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Background: Sport specialization in youth athletes is associated with increased risk for musculoskeletal injury; however, little is known about whether sport specialization is associated with lower extremity movement quality. The purpose of this study was to examine differences in lower extremity movement quality by level of sport specialization in US Service Academy cadets.

Hypothesis: Cadets who report an increased level of sport specialization would have a lower level of movement quality than those who are less specialized.

Study Design: Cross-sectional analysis from an ongoing prospective cohort study.

Level of Evidence: Level 3.

Methods: Cadets completed the Landing Error Scoring System (LESS) and a baseline questionnaire evaluating level of sport specialization during high school. Data were analyzed using separate 1-way analysis of variance models.

Results: Among all participants ($n = 1950$), 1045 (53.6%) reported low sport specialization, 600 (30.8%) reported moderate sport specialization, and 305 (15.6%) reported high sport specialization at the time of data collection during the first week. Ages ranged from 17 to 23 years. Men (1491) and women (459) reported comparable specialization levels ($P = 0.45$). There were no statistically significant differences in lower extremity movement quality by level of specialization for all subjects combined ($P = 0.15$) or when only men were included in the analyses ($P = 0.69$). However, there were statistically significant differences in movement quality by level of specialization in women ($P = 0.02$). Moderately specialized women had the best movement quality (mean, 4.63; SD, 2.21) followed by those with high specialization (mean, 4.90; SD, 2.08) and those with low levels of specialization (mean, 5.23; SD, 2.07).

Conclusion: Women reporting moderate sport specialization had improved movement quality and significantly better LESS scores compared to those with high/low specialization.

Clinical Relevance: Athletes, especially women, should be encouraged to avoid early sport specialization to optimize movement quality, which may affect injury risk.

Keywords: sport volume; military; movement quality

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There has been a recent trend toward younger athletes specializing in a single sport at earlier ages and this has raised many concerns about how sport specialization may affect the development and health of athletes over their life spans. Both the American Academy of Pediatrics and the American Medical Society for Sports Medicine published statements to inform the general population of the potential risks associated with year round high intensity and highly specialized sport training in youth and adolescent athletes.^{3,6} Increased youth sport specialization has been identified as an independent risk factor for lower extremity injury and overuse injuries.^{5,8,17} Despite sport specialization being identified as an independent risk factor for injury, it remains unclear what underlying factors may contribute to this increased risk. Some authors have suggested that participation in multiple sports may be associated with improved decision-making during play and may have a positive influence on gross motor coordination, speed, endurance, and strength, because of enhanced movement quality.^{1,8,14,26} However, whether lower extremity movement quality is associated with level of sports specialization remains unclear.

Increasing concerns about the negative influence of youth sport specialization on health and physical function may also have an impact on military readiness. Musculoskeletal injuries are the leading cause of disability-related medical discharges within the first year of military service.^{21,22} During basic training, approximately 25% of men and 50% of women will have a musculoskeletal injury due to the intense physical requirements and inadequate baseline fitness levels before service.²¹ Increased medical encounters and medical discharges from military service continue to be sources of inefficiency in the armed forces, leading to increased government spending and a decreased human resources.²⁰ A previously published military study has expressed the necessity for preaccession screenings to identify injury risk factors in military service members during initial entry level training.²¹ If sport specialization is indeed associated with poorer movement quality, then this may increase the risk of lower extremity injury in those entering military service. The purpose of this study was to examine differences in lower extremity movement quality by level of sport specialization in cadets entering a US Service Academy. We hypothesized that cadets reporting an increased level of sport specialization would have a lower level of movement quality compared with less specialized individuals.

METHODS

Design and Setting

We conducted a cross-sectional analysis of baseline data from an ongoing prospective cohort study at the United States Military Academy (USMA) at West Point to examine the association between level of sport specialization and lower extremity movement quality, assessed with the Landing Error Scoring System (LESS), on entry to the Academy. Regional Health Command Atlantic Institutional Review Board approval was received before conducting any research.

Participants

All cadets entering the USMA in 2016 and 2017 were recruited to participate in this study and those who provided informed consent were enrolled. There were no exclusion criteria. Participants were briefed on the purposes of the study and discussed their participation with the research staff during their first week at the USMA after in-processing. All participants were aware that their participation was completely voluntary and that they could leave the study at any time. All participants were previously deemed healthy for military service before enrolling in the study through the Department of Defense Medical Evaluation Review Board (DoDMERB). Specifically, all applicants were required to provide a full medical history and undergo a Department of Defense-sponsored physical examination before acceptance to the USMA. Cadet participants were between the ages of 17 and 23 years.

Baseline Study Questionnaire

Cadets who agreed to participate in this study completed a brief questionnaire that was aimed at describing their prior sport specialization level, as well as documenting their demographic information (eg, sex, age, etc), history of injury, and physical activity. The questionnaire was completed within the first week of arrival at the USMA at the time of consent. Cadets were instructed to fill out the questionnaire in accordance with their current activity level, including their high school athletic history. Participants did not use athletic history from earlier in childhood as this would skew the data. Data from admission analysis per year show that 99.4% and 98.7% of incoming 2016 and 2017 cadets participated in varsity athletics in high school, respectively. Sports specialization was operationally defined based on the definition provided by Jayanthi et al¹⁷ who described it as “year-round, intensive training in a single sport at the exclusion of other sports.” The baseline questionnaire included 3 key “yes” or “no” questions designed to assess the level of sports specialization on entry to the USMA. (1) “Can you pick a main sport?” (2) “Did you quit other sports to focus on a main sport?” (3) “Did you train for greater than 8 months in a year for that sport?” Each “yes” or “no” response was coded as a “1” or a “0,” respectively. The sum of the questions’ numerical values gave the participant’s sport specialization level, with 3 points equating to high sport specialization, 2 points equating to moderate sport specialization, and 1 or 0 points equating to low sport specialization.

Baseline LESS Assessment

Lower extremity movement quality can be quantitatively measured using several different assessments. One of these movement screening assessments is the LESS, which is a reliable and valid tool able to differentiate subsequent injury status.^{10,20,23} The LESS evaluates lower extremity movement quality by having participants complete a jump-landing task, which has traditionally been scored by expert raters on 17 high-risk movement patterns or “errors.”^{19,23} A more recent study²⁰ has

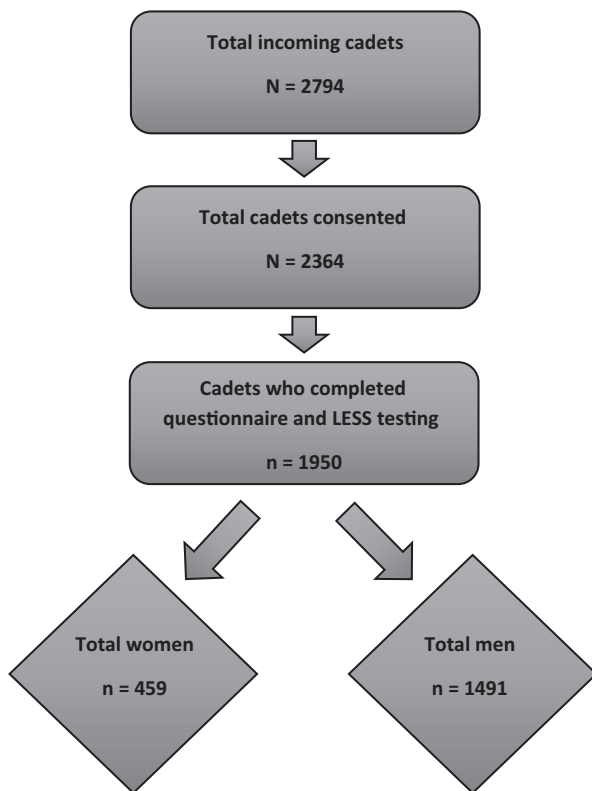


Figure 1. Flowchart depicting patient enrollment process from time of entry to the United States Military Academy to completion of patient questionnaire. LESS, Landing Error Scoring System.

shown that a markerless motion-capture system has similar reliability as the rater reviewed LESS.

We used a markerless motion capture system (PhysiMax Technologies Ltd) to evaluate movement quality with the LESS concurrent with the participants' initial Army Physical Fitness Test during their first week at the USMA. This markerless motion capture system has adequate reliability (average $\kappa = 0.48 \pm 0.40$, average prevalence- and bias-adjusted $\kappa = 0.71 \pm 0.27$; percentage agreement with expert LESS raters = 0.85 ± 0.14) and validity (mean absolute differences 1.13 with a 95% confidence interval of 0.79-1.46) in relation to the standard LESS and 3-dimensional motion analysis.^{10,20} The testing procedure has been well described in previous studies.^{20,23} For each trial, the markerless motion capture system evaluated 15 different dichotomized LESS items and 2 global items.²⁴ These items have previously been described in Pauda et al.²³ Each of the 15 dichotomized items were scored as either a "1" if a movement error was present, or as a "0" if no error existed. Analysis was performed on both legs, and an error was scored if deficiency was consistently shown on either leg in at least 2 of the 3 trials.²⁰ For the 2 global items, a "0," "1," or "2" was assigned based on the amount of movement error present.²⁴ These values

were then summed for the total LESS score out of 17 for that trial, with an average of 3 trials equating their final score.

Statistical Analyses

Initially, descriptive statistics including means and standard deviations, frequencies, and proportions were calculated for important variables of interest. The relationship between total LESS scores (dependent variable), which served as a measure of lower extremity movement quality on entry to military service, and level of sport specialization (independent variable) was evaluated using a 1-way analysis of variance model. Similar analyses stratified by sex were conducted to evaluate the association between level of sport specialization and total LESS scores for men and women independently. If significant main effects were observed, Scheffe post hoc analyses were conducted to evaluate pairwise comparisons by level of sport specialization. Using Hedges's *g* statistics, effect sizes were then calculated with the standard interpretation as follows: small effect = 0.2, medium effect = 0.5, and large effect = 0.8.⁷ All data analyses were completed using STATA SE version 14.2 with an alpha level for pairwise comparison set to $P < 0.05$.

RESULTS

There were a total of 2794 incoming cadets that entered the USMA in the 2016 and 2017 academic year, of whom 2364 (84.6%) consented to participate in this study. Of those cadets who consented, 1950 (82.5%) completed the questionnaire and all LESS jump-landing trials. Only those with complete data were included in the final analyses (Figure 1). Of those participants, 459 (23.5%) cadets were women and 1491 (76.5%) cadets were men. The majority of cadets, 1045 (53.6%), reported low levels of sport specialization, while 600 (30.8%) reported moderate levels of sport specialization, and 305 (15.6%) reported high levels of sport specialization. In the female cohort, the numbers of cadets who reported specialization of high, moderate, and low were 77 (16.8%), 144 (31.4%), and 238 (51.8%), respectively. The numbers of cadets reporting high, moderate, and low specialization in the male cohort were 228 (25.0%), 456 (50.0%), and 228 (25.0%), respectively. Overall, men and women reported comparable levels of sport specialization on entry to the USMA ($P > 0.05$).

There were no significant differences in lower extremity movement quality between level of sport specialization when all subjects were combined ($P > 0.05$) or when only men were included in the analyses ($P > 0.05$); however, there were significant differences in movement quality between levels of sport specialization among women alone ($P = 0.02$) (Table 1). Women who reported moderate levels of sport specialization had significantly fewer movement errors compared to those with low levels of specialization ($P = 0.03$). No other significant differences by level of sport specialization were observed ($P > 0.05$). Overall effect sizes for the female cohort, male cohort, and combined cohort were 0.19, 0.03, and 0.06, respectively, as can be seen in Table 1.

Table 1. Means, standard deviations, and analysis of variance results for Landing Error Scoring System scores based on sports specialization for all participants and stratified by sex

Effect Size	Mean	SD	P
All cadets			0.15
Low (n = 1044) 0.06	4.48	1.96	
Moderate (n = 600) /	4.28	1.94	
High (n = 305) 0.04	4.44	1.89	
Overall effect size = 0.06			
Male cadets			0.69
Low (n = 228) 0.03	4.25	1.87	
Moderate (n = 456) /	4.18	1.84	
High (n = 228) 0.03	4.29	1.81	
Overall effect size = 0.03			
Female cadets			0.02 ^a
Low ^b (n = 238) 0.18	5.23	2.07	
Moderate ^b (n = 144) /	4.63	2.20	
High (n = 77) 0.06	4.90	2.07	
Overall effect size = 0.19			

^aIndicates statistical significance at 0.05 level.

^bModerate sports specialization group performed significantly better than the low sport specialization group.

DISCUSSION

Lower extremity movement quality was associated with level of sport specialization in women reporting to the USMA but not in men. Specifically, women who reported moderate sport specialization had the lowest LESS scores, and therefore, the best lower extremity movement quality, followed by those with high and low specialization. However, only the difference in lower extremity movement quality between women with moderate and low sport specialization was statistically significant. Despite these observed differences in movement quality between the moderate and low specialization groups among women, the effect sizes between these groups were small (0.18).⁷ Furthermore, all the other effect sizes for group comparisons during our study were similarly small (<0.2). In essence, these small effect sizes indicate that the differences found may have limited clinical importance and are likely because of the high power due to the size of our study sample (total n = 1950).

When taking into account the small effect sizes throughout the groups, the main finding of our study was that LESS scores were not significantly influenced by sport specialization except for in

the female athletes, and even in that group, this finding likely had low clinical significance. This is contrary to our hypothesis in which we expected to find the individuals with more diversified athletic backgrounds to have improved LESS scores. In this regard, our findings are consistent with the results reported by Peckham et al²⁴ who evaluated similar variables in a high school athletic population. Both men and women who reported low levels of specialization had the highest LESS scores reflecting the poorest movement quality and those with high levels of specialization had the best movement quality, but there were no statistically significant differences between levels of sport specialization after controlling for sex and site.²⁴ These findings are also reflected in other previous studies, where individuals who are more focused on a single sport are at an increased risk for worse lower extremity movement patterns and vice versa.¹¹ In a systemic review by Bell et al,⁴ highly specialized athletes had a risk ratio of 1.81 for overuse injuries compared to athletes with low specialization and a risk ratio of 1.18 when compared with moderate specialization. One reason why our study may not have detected statistical significance between high sport specialization and LESS movement quality is that the unmeasured variables, namely age of specialization, sport sampling, and volume of

training, may be more responsible for the increased injury risk that has previously been reported.²⁴

The relationship between high levels of sport specialization and increased injuries has been seen in previous studies, as exemplified by Post et al,²⁵ where 2011 youth athletes were examined and increased risk for musculoskeletal injuries were found with high levels of sport specialization, more than 8 months out of the year training in a single sport, and with increased hours per week practicing their particular sport. The relationship between sport specialization and level of neuromuscular control has also been reviewed. DiStefano et al¹² analyzed 355 youth athletes, separating them into single sport or multisport participants and found similar results in that the multisport group was 2.5 times as likely to have superior neuromuscular control as compared with the single sport group. That being said, our results do not show a significant association between movement quality and sports specialization, except in the female population as described below. Despite showing a statistically significant association in the female cohort, this association is small and has questionable clinical relevance.

Statistical significance was only found in the female population. One potential reason for this is the known increased incidence of lower extremity injuries in women because of altered lower extremity kinematics. Anterior cruciate ligament (ACL) injuries in women are 2 to 8 times more likely than in men; however, this increased incidence is not evident before puberty.^{2,13,18,28} There are multiple reasons why female ACL injuries are more common, including increased quadriceps to hamstring ratios when landing, increased valgus malalignment, smaller femoral notch sizes, smaller ACL injuries, and increased Q-angles.^{2,9,13,15,16,27-29}

Our study has multiple strengths, first of which is the large sample size of 1950 participants nearly all of whom participated in varsity high school athletics before arrival for their freshman year at the USMA. Additionally, this study was conducted in a controlled environment, where participants needed to pass an initial physical examination (DoDMERB), as well as be physically fit enough to pass the military entrance fitness test.

This study does have some limitations. As stated earlier, there are some variables that were not measured in this study, particularly age of specialization, sport sampling data, and training volume. These variables may have more of an impact on movement quality than sport specialization. While all participants met military physical fitness and medical standards for service on entry to the study, we did not control for injury history in our analyses. Finally, the LESS scores were obtained at one point in time, on entry to military service, and as a result may not reflect the participant's true movement quality. Furthermore, while the LESS is a validated lower extremity movement assessment tool, it is possible that other differences in movement quality by level of sport specialization not captured by the LESS were present in study participants and may act as confounding variables. LESS evaluation looks at the coronal and sagittal views, potentially missing some valuable

data about the participant's knee movement, especially in the axial plane. These 2 orientations are not able to fully assess the 6 different motions of the knee: flexion, extension, internal rotation, external rotation, varus, and valgus angulation. The gold standard for analyzing dynamic movement quality is still 3-dimensional kinematic analysis. Finally, all identified movement errors are grouped into a single final score, making it difficult to identify what particular criteria are deficient.

CONCLUSION

The results of this study are in contrast to our initial hypothesis. The only statistically significant finding was that female cadets who reported moderate sport specialization had better movement quality when compared with female cadets who reported low sport specialization on entry to the USMA. However, with the small effect sizes observed for comparisons between level of sport specialization, the clinical relevance of these baseline differences in lower extremity movement quality by level of sport specialization is questionable. Our study suggests that movement quality may be less reliant on sport specialization and more impacted by other nonmeasured variables.

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