

Differences in Hamstring Flexibility between Athletes in the Chilean National Wushu Team versus Athletes not in the Chilean National Wushu Team

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Abstract—This study evaluates hamstring flexibility among junior athletes practicing modern Taolu Wushu using the Sit and Reach test. The cross-sectional analysis included 32 participants, evenly split between members and non-members of the national team. Results demonstrated that national team members exhibited significantly higher flexibility levels compared to their non-team counterparts ($p < .01$, $d = 0.707$), highlighting hamstring flexibility as a critical factor for national team selection in Wushu. Spearman's correlation analyses further revealed significant associations between flexibility and phenotypic variables such as age and height, particularly within the national team cohort, suggesting these traits may influence or contribute to the observed differences in flexibility. These findings support the use of the Sit and Reach test as a simple yet effective tool for assessing hamstring flexibility, which can help coaches identify potential national team candidates and tailor training programs to enhance flexibility. The outcomes align with previous research indicating higher flexibility levels in athletes of national teams across various sports, underscoring the importance of flexibility in competitive success and athlete selection processes.

Introduction

Modern Competitive Wushu, based on traditional Chinese martial arts, has gained significant international recognition over recent decades, with numerous national and international competitions emerging. One key discipline within Modern Wushu is Taolu, which involves performing choreographed movements against imaginary opponents, and demands high technical, performance, and difficulty standards¹⁻³. To excel at the highest levels, Wushu athletes must develop not only their technical skills and lower limb power but crucially, their flexibility—particularly hamstring flexibility, which is vital for performing complex aerial kicks requiring extensive hip flexion and knee extension⁴⁻⁶.

Furthermore, young athletes' athletic development plan should include training strategies for optimal development of the hamstrings muscles⁷. The hamstrings muscles origin from the ischial tuberosity, and thus hamstring flexibility can affect posture and spine alignment during growth; for example, noted that an excessive shortening of these muscles increases the tension on the pelvis and, consequently, may produce changes in the spine morphology^{8,9}. Therefore, it was deduced that hamstring flexibility training should be included early in youth soccer training programs, as they tend to become tighter throughout their biological maturation, but it is unclear

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whether this is due to physical growth or it is influenced by daily routine and practice¹⁰. Even though hamstring injuries occur at a lower incidence in youth players than in adult populations, a study that was conducted among 623 young players of Barcelona Football Club revealed an incidence of damage estimate at 0.041 for biceps femoris and 0.061 for semitendinosus and semimembranosus for every 1,000 hours of soccer practice¹¹.

This study aims to add to the prior studies, and shed light on the critical role of hamstring flexibility in Wushu by comparing athletes from the Chilean National Team with those who were not selected. By identifying potential disparities in flexibility, this research seeks to ascertain whether hamstring flexibility serves as a predictive measure for national team selection. It is hypothesized that athletes in the National Team will demonstrate superior flexibility compared to their non-member counterparts, suggesting that targeted flexibility training should be a focal point in Wushu training regimes.

Methods

For the preliminary study we employed a quantitative, descriptive, cross-sectional, and non-experimental research design. The participants were Junior Wushu athletes in Modern Taolu who were participants in the Second Modern Wushu Championship of Chile in 2022. The sample consisted of athletes with varying ages, years of training, genders, clubs, and anthropometric measurements. A detailed description of the sample characteristics is provided in the Results section. The methodology used in this study was approved by the Institutional Board of the Chilean Wushu Federation and followed the Declaration of Helsinki.

The Sit and Reach test (Eurofit) was used to assess hamstring flexibility in all studied groups. The test was conducted during the National Wushu Championship in Modern Taolu, in which the junior Wushu athletes participated. All measurements were taken before the athletes' competition events. A standardized 10-minute warm-up was

performed before the assessment, with the test procedure explained to the participants and administered according to the appropriate protocol. The box utilized was 35 x 45 x 32 centimeters with starting measurement at the 15cm mark. Three trials were allowed for each individual with the maximum value used for statistical analysis. Finally, the test was conducted by two health-trained professionals, who were trained in the fields of physical therapy and physical education (HT & JS).

Statistical Analysis

Microsoft Excel was used to input the data. Subsequently, the data was imported into RStudio for the statistical analysis using the R programming language¹². Descriptive statistics, including medians and interquartile ranges (IQR), were initially calculated to summarize the demographic and physical characteristics of the athletes. This was followed by inferential statistical tests to explore the differences in hamstring flexibility between junior Wushu athletes who were part of the national team and those who were not. To examine the differences between the two groups (National Team vs. Non-Team), a two-sample Mann-Whitney U test was employed due to the non-normal distribution of the Sit and Reach test scores. This non-parametric test was chosen to compare the median scores of hamstring flexibility, providing a robust method for analyzing skewed data or data with outliers. Following the comparative analysis, Spearman's rank correlation coefficients were calculated to assess the relationships between flexibility (as measured by the Sit and Reach scores) and several phenotypic variables including age, height, and training experience. Spearman's method was selected due to its non-parametric nature, making it suitable for data that do not meet the assumptions of normality and linearity required for Pearson's correlation. Subgroup analyses were conducted to further explore these relationships within different cohorts defined by team membership and sex. This approach allowed for an assessment of how these variables interacted with flexibility within and across different groups. Statistical significance was set at $p < .05$ for all tests.

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Characteristic	No Team, N = 16 ¹	National Team, N = 16 ¹	p-value ²
Age (yrs)	10.50 (6.00, 12.00)	12.50 (9.00, 17.00)	.011
Weight (kg)	40 (22, 63)	48 (33, 85)	.11
Height (cm)	1.41 (1.18, 1.67)	1.51 (1.31, 1.86)	.048
BMI (kg/m ²)	19.09 (15.80, 29.50)	20.61 (16.91, 24.84)	.4
Training experience (yrs)	0.75 (0.50, 4.00)	3.00 (1.00, 10.00)	<.001
Sit and Reach score (cm)	17 (4, 31)	28 (21, 41)	<.001
Biological Sex			.7
Female	6 (38%)	7 (44%)	
Male	10 (63%)	9 (56%)	

¹ Median (Range); n (%)

² Wilcoxon rank sum test; Wilcoxon rank sum exact test; Pearson's Chi-squared test

Table 1. Descriptive of Junior Wushu Athletes.

Results from the statistical tests were used to guide conclusions about the factors influencing hamstring flexibility in junior Wushu athletes, and to formulate recommendations for training practices.

Results - Demographics

The study encompassed 32 junior Wushu athletes, categorized by group affiliation and sex. Sixteen athletes were part of the national team, and sixteen were not, with a gender distribution of 13 females and 19 males. These athletes were further divided into four subgroups: 10 male athletes not on the national team, 9 male athletes on the national team, 6 female athletes not on the team, and 7 female athletes on the national team.

Demographic and physical characteristics varied notably between groups. The median age for athletes not on the national team was 10.50 years (range 6.00-12.00 years) compared to 12.50 years (range 9.00-17.00 years) for those on the national team. Median weight was 40 kg (range 22-63 kg) for non national team athletes and 48 kg (range 33-

85 kg) for national team members. Heights averaged at 1.41 meters (range 1.18-1.67 meters) for athletes not on the national team and 1.51 meters (range 1.31-1.86 meters) for those on the national team. The median BMI was slightly higher in the national team group at 20.61 kg/m² (range 16.91-24.84 kg/m²) compared to 19.09 kg/m² (range 15.80-29.50 kg/m²) for non national team members. Training experience also showed significant differences, with non national team athletes having a median of 0.75 years (range 0.50-4.00 years) versus 3.00 years (range 1.00-10.00 years) for national team athletes.

Sit and Reach test scores further highlighted these disparities, with national team athletes achieving a median score of 28 cm (range 21-41 cm) compared to 17 cm (range 4-31 cm) for those not on the national team, underscoring the better flexibility in the national team. These demographic and performance metrics are detailed in Table 1, providing a comprehensive overview of the athlete's characteristics and their performance variability.

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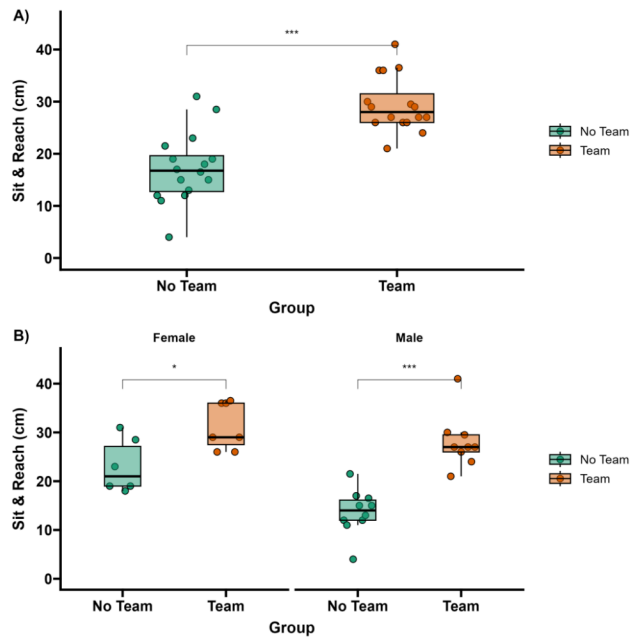


Figure 1. A) comparison of hamstring flexibility between groups; B) comparison between groups by sex.

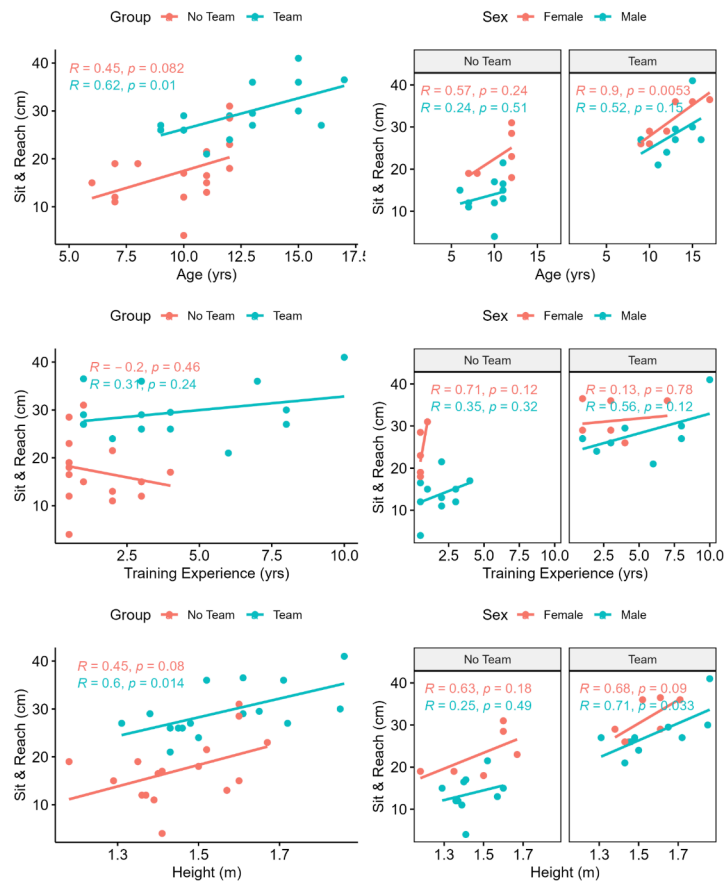


Figure 2. Associations between Sit & Reach (cm) with Age (yrs) (top panel), Training experience (yrs) (medium panel), and Height (cm) (lower panel) as a group and by biological sex.

Group Differences in Hamstring Flexibility

In this study, we investigated the effects of group affiliation and biological sex on the flexibility of junior Wushu athletes using the Sit and Reach test. Two-way ANOVA results showed significant main effects for both Group ($F(1, 28) = 46.004, p < .001$) and Sex ($F(1, 28) = 11.364, p = .0022$), indicating substantial differences in flexibility based on both factors, while the interaction effect was not significant ($F(1, 28) = 2.866, p = .1015$). To confirm these findings under the assumption of non-normal data distributions, we employed a Wilcoxon rank-sum test, which corroborated the ANOVA results, demonstrating a significant difference in Sit and Reach scores between the National Team and Non-Team groups ($W = 22, p < .001$). The effect size calculated via the Wilcoxon method was substantial ($d = 0.707$), further substantiating the practical significance of group affiliation in influencing athlete flexibility, irrespective of sex. These findings thus support prior studies, and membership in the National Team can be associated with superior flexibility, highlighting the potential benefits of structured training programs in enhancing athletic performance.

Correlation Analyzes

In an analysis of junior Wushu athletes, Spearman's correlation coefficients were calculated to assess the relationships between Sit & Reach flexibility scores and several phenotypic variables across different subgroups, categorized by team membership and sex. The results revealed a significant positive correlation between age and Sit & Reach scores among athletes in the national team ($R = 0.62, p = 0.01$), suggesting that older athletes in this group tend to exhibit greater flexibility. Conversely, this correlation was not significant for athletes not on the team ($R = 0.45, p = 0.082$). With respect to flexibility, training experience did not show a significant correlation with Sit & Reach scores in either group, indicating that the length of training does not have a discernible impact on flexibility within this sample (Team: $R = 0.31, p = 0.24$; No Team: $R = -0.2, p = .46$). However, height was

significantly correlated with Sit & Reach scores in the national team ($R = 0.6, p = .014$), but not in the non-team group ($R = 0.45, p = .08$), suggesting that taller athletes within the national team are more likely to achieve better flexibility scores. These findings highlight the influence of age and physical stature on flexibility in competitive athletes, with varying impacts observed across different group and sex categories.

Discussion

This study examined the differences in hamstring flexibility, as measured by the Sit and Reach test, between junior Wushu athletes who are part of the national team and those who are not. Our findings revealed significant differences, with national team athletes demonstrating markedly greater flexibility. This underscores the potential importance of hamstring flexibility in enhancing performance at the national level, aligning with the inclusion of flexibility tests in selection criteria by elite teams such as the Beijing Wushu Team. Further analysis using Spearman correlations explored relationships between flexibility and phenotypic variables such as age, height, and training experience. Notably, age and height in team athletes showed significant positive correlations with flexibility, suggesting that these factors may influence or contribute to the superior performance in flexibility tests observed among national team members. However, training experience, did not correlate significantly with flexibility, indicating that other factors, possibly including inherent physiological characteristics or training quality, might play more pivotal roles.

Our study's findings are consistent with previous research on hamstring flexibility in athletes from various sports. For instance, a study found that karate athletes had significantly better hamstring flexibility than non-athletes, as measured by the Sit and Reach test⁸. Similarly, another study reported that high-level soccer players exhibited greater hamstring flexibility compared to lower-level players¹³. Moreover, hamstring flexibility has been shown to be an essential factor for athletic performance in several

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sports, including gymnastics, dance, and martial arts^{14,15}. Improved flexibility can lead to better technique execution, reduced risk of injury, and enhanced overall performance¹⁶. Our study extends this research by focusing on junior Wushu athletes and demonstrating a significant difference in hamstring flexibility between those who are part of the national team and those who are not. This finding reinforces the importance of hamstring flexibility in athletic performance and highlights the need for targeted flexibility training in Wushu and other sports that require high levels of flexibility.

Our study employed the Eurofit Test Battery Sit and Reach protocol (Committee of Experts on Sports Research, 1988), wherein the "0" point for initiating measurements was positioned at 15 cm from the edge of the feet, differing from the ACSM protocol, which places it at 23 cm (9 inches) from the edge of the feet¹⁷. To compare our results with other studies conducted using the ACSM protocol, we adjusted the corresponding values. Consequently, we observed that the adjusted mean values of Chilean Team athletes, at 37.4 cm, were similar to those found by Sukanti et al.¹⁸ in their study of 50 Indonesian wushu athletes aged between 8 and 15 years, who achieved 36 cm. The values for Chilean Non-Team athletes were lower than those found in this study, at 25.2 cm. On the other hand, Huang et al. assessed 30 Taiwanese national ranking wushu athletes aged between 12 and 15 years, who had a mean of 47.6 cm, demonstrating a significant superiority compared to the values discovered in our Chilean study¹⁹. Nonetheless, the values for Chilean wushu athletes in the Team from our research showed higher values than basketball athletes (mean = 31.5 cm), track and field athletes (mean = 30.47 cm), and general student athletes (mean = 30.27 cm) evaluated in Huang's study. An intriguing observation is that the values for Chilean junior wushu athletes, both Team and Non-Team, are considerably lower than the values found by Aedo-Muñoz²⁰ in their study of 424 Chilean athletes aged between 12 and 18 years from various sports (aquatic sports, hunting, extreme sports, combat sports, team sports,

track and field, and artistic gymnastics), which show mean values ranging between 45 and 53 cm for the evaluated athletes, even in those sports that do not require significant hamstring flexibility, such as hunting or team sports²⁰.

However, any discussion generated by comparing values with other authors should be approached cautiously, as the samples do differ in size, age, training duration, and other factors. Moreover, in the case of our study, it should be considered that the evaluated athletes were only recently returning to competitions following the confinement due to the Covid-19 pandemic, and therefore many stated their athletic performance levels were not at their usual standards. Lastly, the discrepancy between scores could mostly be attributed to differences in protocols from both studies, the ACSM and the Eurofit Test Battery Sit and Reach protocol.

Limitations and Future Directions

The study is not without limitations. The small sample size may restrict the generalizability of our findings, and the cross-sectional design limits causal inferences. Future research should include larger, more diverse samples and consider longitudinal designs to better understand the development of flexibility over time and its impact on national team selection. Additionally, considering other performance-influencing factors such as technical skills, psychological attributes, and overall physical conditioning in conjunction with flexibility could provide a more comprehensive understanding of what influences junior Wushu athletes' performance.

Conclusions

In conclusion, our study demonstrates that significant differences in hamstring flexibility exist between junior Wushu athletes in the national team and those who are not, with flexibility potentially serving as a predictive factor for national team membership. This highlights the importance of incorporating flexibility training into

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coaching and training regimes for athletes aspiring to reach national levels. Further studies are recommended to explore additional factors influencing athletic performance and to confirm the predictive value of flexibility in athlete selection processes.

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