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Countermovement jump performance in Malaysian young wushu athletes: normative values and sex-based differences

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ORIGINAL PAPER

Abstract

Wushu, commonly known as kung-fu, is a demanding sport requiring rapid force application to achieve significant vertical jump heights. These jumps are integral for executing complex aerial tasks and obtaining higher performance scores. *Purpose*: This study aimed to establish normative data for countermovement jump (CMJ) performance parameters in elite wushu athletes. *Methods*: A cross-sectional design was implemented at the 2022 Malaysia Games (SUKMA) wushu competition with 115 athletes (males=67). Each athlete performed three CMJs with hands akimbo on a pair of force platforms. Performance and biomechanical data (vertical jump height, peak relative propulsive power, peak relative propulsive force, modified reactive strength index, and relative propulsive net impulse) were collected using Hawkins Dynamics software. An ANCOVA was used to compare CMJ parameters across sex and events, controlling for age and body mass. Normative data were established using t-scores. *Results*: The ANCOVA indicated that CMJ and biomechanical variables differed by sex and age ($p<0.01$), but not by event. *Conclusion*: These normative values provide a baseline for understanding CMJ performance in elite wushu athletes and may guide further exploration of training adaptations, injury risk assessment, and performance optimization. However, additional research is warranted to fully validate and expand on the potential practical applications of these findings.

Keywords: Martial arts; combat sports; wushu, vertical jump; biomechanics; young athletes; sport science.

Rendimiento en el salto con contramovimiento en jóvenes atletas malayos de wushu: valores normativos y diferencias por sexo

Resumen

El wushu, comúnmente conocido como kung-fu, es un deporte exigente que requiere una rápida aplicación de fuerza para alcanzar alturas significativas en los saltos verticales. Estos saltos son fundamentales para ejecutar tareas aéreas complejas y obtener puntuaciones más altas en las competiciones. *Objetivo*: El objetivo de este estudio fue establecer datos normativos para los parámetros de rendimiento del salto con contramovimiento (CMJ) en

Desempenho no salto com contra-movimento em jovens atletas de wushu da Malásia: valores normativos e diferenças baseadas no sexo

Resumo

O wushu, comumente conhecido como Kung-Fu, é um desporto exigente que requer a aplicação rápida de força para alcançar alturas significativas de salto vertical. Esses saltos são essenciais para executar tarefas aéreas complexas e obter pontuações de desempenho mais altas. *Objetivo*: Este estudo teve como objetivo estabelecer dados normativos para os parâmetros de desempenho do salto contra-movimento (CMJ) em atletas de elite do

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atletas de élite de wushu. *Métodos*: Se implementó un diseño transversal en la competición de wushu de los Juegos de Malasia 2022 (SUKMA) con 115 atletas (67 hombres). Cada atleta realizó tres CMJ con las manos en la cintura sobre un par de plataformas de fuerza. Los datos de rendimiento y biomecánicos (altura del salto vertical, potencia propulsiva relativa máxima, fuerza propulsiva relativa máxima, índice de fuerza reactiva modificado e impulso propulsivo relativo neto) se recopilaron utilizando el software Hawkins Dynamics. Se utilizó un ANCOVA para comparar los parámetros del CMJ entre sexos y eventos, controlando la edad y la masa corporal. Los datos normativos se establecieron utilizando puntuaciones t. *Resultados*: El ANCOVA indicó que las variables del CMJ y biomecánicas diferían según el sexo y la edad ($p<0,01$), pero no según la prueba. *Conclusión*: Estos valores normativos proporcionan una base para comprender el rendimiento del CMJ en atletas de élite de wushu y pueden orientar la exploración ulterior de las adaptaciones del entrenamiento, la evaluación del riesgo de lesiones y la optimización del rendimiento. Sin embargo, se necesitan más investigaciones para validar y ampliar plenamente las posibles aplicaciones prácticas de estos hallazgos.

Palabras clave: Artes marciales; deportes de combate; wushu; salto vertical; biomecánica; atletas jóvenes; ciencias del deporte.

wushu. *Métodos*: Um desenho transversal foi implementado na competição de wushu dos Jogos da Malásia de 2022 (SUKMA) com 115 atletas (homens = 67). Cada atleta realizou três CMJs com as mãos na cintura em um par de plataformas de força. Os dados de desempenho e biomecânicos (altura do salto vertical, potência propulsora relativa máxima, força propulsora relativa máxima, índice de força reativa modificado e impulso propulsor líquido relativo) foram coletados usando o software Hawkins Dynamics. Uma ANCOVA foi usada para comparar os parâmetros do CMJ entre sexos e eventos, controlando a idade e a massa corporal. Os dados normativos foram estabelecidos usando pontuações t. *Resultados*: A ANCOVA indicou que as variáveis CMJ e biomecânicas diferiam por sexo e idade ($p<0,01$), mas não por evento. *Conclusão*: Estes valores normativos fornecem uma base para compreender o desempenho CMJ em atletas de elite de wushu e podem orientar uma exploração mais aprofundada das adaptações do treino, avaliação do risco de lesões e otimização do desempenho. No entanto, são necessárias pesquisas adicionais para validar e expandir totalmente as potenciais aplicações práticas destas descobertas.

Palavras-chave: Artes marciais; desportos de combate; wushu; salto vertical; biomecânica; jovens atletas; ciência do desporto.

1. Introduction

Vertical jump performance is widely recognized by strength and conditioning professionals as a key measure of athletic ability and an important contributor to injury prevention (Hoffman et al., 2005; Markovic et al., 2004). Parameters such as jump height, force output, and reactive strength indices provide insight into an athlete's neuromuscular capacity, identifying areas for improvement that may boost performance and lower injury risk (Meeuwisse et al., 2003).

Wushu (a.k.a., kung fu) is a martial art form characterized by complex aerial techniques that require both explosive lower-body power and precise body control. Recent conference abstracts and pilot investigations have reported the utility of the countermovement jump (CMJ) in monitoring performance changes among wushu athletes, particularly throughout disruptive periods like the COVID-19 pandemic (Montalvo et al., 2022; Tan et al., 2022). These preliminary findings suggest that wushu athletes exhibit distinct jump profiles that likely reflect the unique physical demands and lower-limb injury profiles of this sport (Fong et al., 2007; Montalvo et al., 2022; Tan et al., 2017, 2024). Notably, wushu-related injuries are reportedly more common in the lower limbs (Montalvo et al., 2020), emphasizing the importance of vertical jump performance as both a performance metric and potential injury predictor.

Despite the clear importance of vertical jump performance in wushu, there is a lack of comprehensive, sport-specific normative data to guide coaches, practitioners, and researchers. In sports such as rugby, establishing CMJ benchmarks has already proven valuable for tailoring training protocols and monitoring athlete development (McMahon et al., 2022). Creating such references for wushu athletes would enable more accurate comparisons of performance, help diagnose deficiencies, and potentially inform injury mitigation strategies. Notably, wushu competitions include multiple disciplines or "routines"—for example, chang quan (long fist), nan quan (southern fist), taijiquan (tai chi), and various short- and long-weapon events—each with its own stylistic emphasis and associated demands on vertical jump ability (Tan et al., 2017). Exploring whether CMJ performance differs among these sub-disciplines offers an opportunity to refine training and injury-prevention strategies even further. For instance, chang quan ("long fist") emphasizes extended leaps, whirlwind kicks, and large-amplitude body rotations, demanding high take-off power and hip–knee extension velocities; nan quan ("southern fist") is performed from deep, static stances and relies on short-range, rapid trunk-and-upper-limb strikes that still require explosive leg drive, but with a lower jump

amplitude than chang quan (Tan et al., 2017). By contrast, taijiquan ("tai chi") is executed at a deliberately slow, continuous tempo and elicits only moderate cardiorespiratory stress—its metabolic cost is ≈40–50 % lower than brisk walking of similar duration (Hui et al., 2009). These martial arts styles contrasts imply that countermovement-jump mechanics (e.g., depth, impulse, and reactive-strength indices) may differ across routines and justify analysing CMJ profiles by event.

Accordingly, the primary objective of this study was to establish normative data for CMJ performance and biomechanical parameters in national-level wushu athletes. A secondary aim was to determine whether performance differs by wushu event (routine) and sex. Given the central role of vertical jump capacity in wushu's aerial techniques, we hypothesized that these parameters would differ across sub-disciplines and between sexes.

2. Methods

A total of 115 national-level Malaysian wushu athletes participated in the study, comprising 67 males (18.1 ± 2.4 y, 60.2 ± 6.9 kg) and 48 females (17.4 ± 2.8 y, 50.4 ± 5.3 kg), participated in this cross-sectional study, implemented at the 2022 Malaysia Games (SUKMA) wushu event. Although the standard age limit for SUKMA is typically under 21, an exception was made for this edition—allowing athletes up to 23 years of age to compete—due to COVID-19-related disruptions. Because many participants were under 18 years of age, we obtained informed consent from each athlete and, when applicable, parental or guardian consent in accordance with institutional guidelines and the Declaration of Helsinki. The distribution of athletes spanned multiple wushu events, including empty-hand routines (long fist "chang quan," southern fist "nan quan," and tai chi "taiji quan") and weapon routines (staff "gunshu," broadsword "daoshu," straight sword "jianshu," spear "qiangshu," southern sword "nandao," southern staff "nangun," and taiji sword "taijijian"). Full details are provided in Table 1. Since our main objective was exploratory—proposing normative jump data for youth athletes—no formal sample size calculation was conducted (Lakens, 2022). All research activities were approved by the Malaysia Institutional Review Board or Ethics Committee.

Prior to competing in the SUKMA event, athletes performed a self-selected warm-up. No standardized warm-up procedures were enforced in order to avoid altering each athlete's established stretching routine, which could have affected their competition performance (Chaabene et al., 2019; Montalvo & Dorgo, 2019). Three CMJs with hands akimbo were performed on two uni-axial force platforms sampling at 1,000 Hz (Hawkins Dynamics, ME, USA). A demonstration of proper CMJ form was provided, followed by two or three familiarization trials prior to data collection. A self-selected rest interval (commonly ~15 seconds) was used between recorded trials to minimize residual fatigue. A verbal cue of jumping as high as possible was given to all athletes. Performance, kinematic, and kinetic components of the CMJ were obtained via Hawkins Dynamics software (v.8.6.1). Vertical Jump Height was derived using a velocity-based approach in which the vertical ground reaction force is divided by body mass and integrated over time to obtain the system's center-of-mass velocity. Jump height was calculated from the velocity at take-off, defined as the instant the force dropped below a threshold indicating the end of contact. Modified Reactive Strength Index (mRSI) was computed by dividing the time from movement onset to take-off by jump height. The "modified" designation reflects that this ratio emphasizes how quickly an athlete completes the countermovement phase relative to jump height, differing from the traditional RSI formula (jump height ÷ ground contact time).

For the kinetic metrics, peak relative propulsive power ($W \cdot kg^{-1}$) and peak relative propulsive force ($N \cdot kg^{-1}$) is the maximal force and mechanical power output produced during the concentric (propulsive) phase, also normalized to body mass. Relative propulsive net impulse ($N \cdot s \cdot kg^{-1}$) is calculated by integrating only the positive (propulsive) portion of the force-time curve above body weight, again normalized to body mass. These normalized values allow for direct comparisons among athletes with different body masses (Bishop et al., 2022; Kirby et al., 2011; Montalvo et al., 2024). Furthermore, the selection of these vertical jump performance variables was conducted based on the literature and our previous investigations that show propulsive metrics, including mRSI, are highly associated with vertical jump performance (Bishop et al., 2022; Erik Tan et al., 2021; Tan et al., 2023). No filter was applied to any of the signals derived from the ground reaction force plates (Harry et al., 2022). We did not strictly standardized technique to avoid artificially constraining athletes' natural

jumping strategies, as this can affect the reliability of force-time metrics (Montalvo et al., 2024; Pérez-Castilla et al., 2021). Each athlete's three recorded jumps were averaged for the final analysis (see Figure 1).

All data were imported from Hawkins Dynamics software into RStudio (version 4.5.0) for analysis (RStudio, 2020). Descriptive statistics (mean, standard deviation, median, minimum, and maximum) were first calculated for all variables. Normality assumptions were assessed using the Shapiro-Wilk test.

Comparison Across Events. An ANCOVA was used to assess differences in jump height across the three primary wushu events (chang quan, nan quan, taijiquan), with sex and age included as covariates. Model assumptions (linearity, normality of residuals, homogeneity of variance) were verified and met. Comparison Between Sexes. For the remaining CMJ variables—mRSI, relative net impulse, relative peak propulsive power, and relative peak propulsive force—Welch's two-sample *t*-tests were conducted to compare males and females. This approach was chosen because it does not assume equal variances between groups.

Figure 1. Athlete performing a countermovement jump on a two-uniaxial force platform.

Normative Data and Significance. Normative data were generated using *t*-scores by sex for five variables (jump height, mRSI, relative net impulse, relative peak propulsive power, and relative peak propulsive force). The following classification scheme was applied to *t*-scores: > 80 ~ 'Excellent', <= 80 & > 70 ~ 'Very Good', <= 70 & > 60 ~ 'Good', <= 60 & > 50 ~ 'Above Average', <= 50 & > 45 ~ 'Average', <= 45 & > 40 ~ 'Below Average', <= 40 & > 30 ~ 'Poor',<= 30 & > 20 ~ 'Very Poor', <= 20 ~ 'Extremely Poor'. This classification was produced for the following metrics: Jump height, mRSI, peak propulsive force, relative peak propulsive power, and relative net propulsive impulse. Significance was considered *priori* at an alpha level of 0.05.

3. Results

3.1. Demographics

In this study males had a slightly higher average age of 18.1 years (SD=2.36) (full description of the sample size, age, weight, and other parameters are highlighted in Table 1). Findings from the ANCOVA indicated that there was a significant difference in jump height across sex (male and female) ($p<0.01$) and age ($p=0.04$), but not across competition events ($p=0.18$). Table 1 also shows the distribution of primary wushu (empty hand), short weapon and long weapon events.

Table 1. Description of participants and event distribution

Variables	Female (n=48)	Male (n=67)	Overall (n=115)
Age (yrs) – M (SD)	17.4 (2.76)	18.1 (2.36)	17.8 (2.54)
Body mass (kg) - M (SD)	50.4 (5.26)	60.2 (6.87)	56.1 (7.90)
Empty Hand event			
Changquan	23 (47.9%)	33 (49.3%)	56 (48.7%)
Nanquan	9 (18.8%)	22 (32.8%)	31 (27.0%)
Taijiquan	16 (33.3%)	12 (17.9%)	28 (24.3%)
Short Weapon event			
Daoshu	13 (27.1%)	19 (28.4%)	32 (27.8%)
Jianshu	11 (22.9%)	14 (20.9%)	25 (21.7%)
Nandao	9 (18.8%)	21 (31.3%)	30 (26.1%)
Taijijian	15 (31.3%)	0 (0%)	15 (13.0%)
Taijian (Sword)	0 (0%)	12 (17.9%)	12 (10.4%)
Long Weapon event			
Gunshu	13 (27.1%)	19 (28.4%)	32 (27.8%)
Nangun	9 (18.8%)	20 (29.9%)	29 (25.2%)
Qiangshu	11 (22.9%)	15 (22.4%)	26 (22.6%)

A series of Welch t-tests showed significant sex differences in all countermovement-jump variables—jump height, mRSI, relative net impulse, relative peak propulsive power and relative propulsive forces (all $p < 0.05$; Table 2). Because of this strong sex effect, we present normative reference values stratified by sex.

Table 2. Description of vertical jump variables

Variable	Females - M (SD) N = 48[1]	Males - M (SD) N = 67	p-value[1]
Jump Height (m)	0.37 (0.05)	0.49 (0.06)	<0.001
mRSI	0.44 (0.09)	0.56 (0.10)	<0.001
Rel. Net Impulse (Ns/kg)	2.72 (0.18)	3.13 (0.19)	<0.001
Rel. Peak Propulsive Power (W/kg)	52.32 (4.92)	64.45 (6.02)	<0.001
Rel. Peak Propulsive Force (N/kg)	2.70 (0.52)	2.94 (0.50)	0.015

Note: [1] Welch Two Sample t-test a. mRSI: Modified Reactive Strength Index, a measure of an athlete's ability to change quickly from an eccentric to concentric contraction. Rel. Net Impulse: Relative Net Impulse, measured in Newton-seconds per kilogram of body weight, represents the change in momentum during the propulsive phase of the jump. Rel. Peak Propulsive Power: Relative Peak Propulsive Power, measured in Watts per kilogram of body weight, indicates the highest rate of work done during the propulsive phase of the jump. Rel. Peak Propulsive Force: Relative Peak Propulsive Force, measured in Newtons per kilogram of body weight, represents the highest force exerted during the propulsive phase of the jump.

3.2. Proposed normative data and T-scores

We generated normative data for five key CMJ variables—vertical jump height (m), mRSI, relative propulsive net impulse (Ns·kg), peak relative propulsive power (W/kg), and peak relative propulsive force (N/kg)—stratified by sex (male and female). These data are presented in Figures 1 and 2 and Tables 3 and 4. In certain instances, some lower-end classification categories (e.g., "Very Poor," "Extremely Poor") were omitted when no athletes' scores approached those thresholds, resulting in "Poor" serving as the lowest observed classification. For instance, Table 3 provides the classification bands for male wushu athletes, while Table 4 presents the corresponding bands for female wushu athletes.

Table 3. Normative classifications for Countermovement Jump (CMJ) metrics in male wushu athletes

Description	Jump height (m)	mRSI	Rel. net impulse (Ns·kg)	Rel. peak propulsive power (W/kg)	Rel. peak propulsive force (N/kg)
Excellent	> 0.68	> 0.82	> 3.7	> 84	> 4.6
Very Good	0.62 - 0.68	0.76 - 0.82	3.5 - 3.7	> 84	4 - 4.6
Good	0.55 - 0.62	0.66 - 0.76	3.3 - 3.5	71 - 73	3.4 - 4
Above Average	0.5 - 0.55	0.56 - 0.66	3.1 - 3.3	64 - 71	3 - 3.4
Average	0.47 - 0.5	0.51 - 0.56	3 - 3.1	61 - 64	2.7 - 3
Below Average	0.44 - 0.47	0.47 - 0.51	3 - 3	59 - 61	2.5 - 2.7
Poor	0.38 - 0.44	0.38 - 0.47	2.8 - 3	53 - 59	2.4 - 2.5
Very Poor	0.36 - 0.38	0.3 - 0.38	2.7 - 2.8	49 - 53	< 2.4
Extremely Poor	< 0.36	< 0.3	< 2.7	< 49	< 2.4

Note: mRSI: Modified Reactive Strength Index. Rel. net impulse: Relative net impulse. Rel. peak propulsive power: Relative peak propulsive power. Rel. peak propulsive force: Relative peak propulsive force. Ranges are expressed using a dash (e.g., '0.50 - 0.55'). Some categories, particularly 'Very Good', show identical upper and lower bounds due to rounding or limited data in these ranges. For 'Excellent' and some 'Very Good' categories, only a lower bound is provided. 'Extremely Poor' categories are denoted with '<' to indicate performance below the stated value. Users should interpret these ranges as guidelines, understanding that there may be some overlap between adjacent categories, especially near the boundaries.

Table 4. Normative classifications for Countermovement Jump (CMJ) metrics in female wushu athletes

Description	Jump height (m)	mRSI	Rel. net impulse (Ns·kg)	Rel. peak propulsive power (W/kg)	Rel. peak propulsive force (N/kg)
Excellent	> 0.49	> 0.62	> 3.1	> 62	> 4.5
Very Good	0.49 - 0.49	0.62 - 0.62	3.1 - 3.1	> 62	3.8 - 4.5
Good	0.42 - 0.49	0.53 - 0.62	2.9 - 3.1	58 - 62	3.2 - 3.8
Above Average	0.37 - 0.42	0.44 - 0.53	2.7 - 2.9	53 - 58	2.7 - 3.2
Average	0.35 - 0.37	0.41 - 0.44	2.6 - 2.7	50 - 53	2.5 - 2.7
Below Average	0.33 - 0.35	0.36 - 0.41	2.6 - 2.6	48 - 50	2.2 - 2.5
Poor	0.29 - 0.33	0.27 - 0.36	2.4 - 2.6	45 - 48	2 - 2.2
Very Poor	0.27 - 0.29	0.26 - 0.27	2.3 - 2.4	42 - 45	< 2
Extremely Poor	< 0.27	< 0.26	< 2.3	< 42	< 2

Note: mRSI: Modified Reactive Strength Index. Rel. net impulse: Relative net impulse. Rel. peak propulsive power: Relative peak propulsive power. Rel. peak propulsive force: Relative peak propulsive force. Ranges are expressed using a dash (e.g., '0.50 - 0.55'). Some categories, particularly 'Very Good', show identical upper and lower bounds due to rounding or limited data in these ranges. For 'Excellent' and some 'Very Good' categories, only a lower bound is provided. 'Extremely Poor' categories are denoted with '<' to indicate performance below the stated value. Users should interpret these ranges as guidelines, understanding that there may be some overlap between adjacent categories, especially near the boundaries.

4. Discussion

The primary objective of this investigation was to establish normative data for key countermovement jump (CMJ) parameters in wushu athletes. We also explored whether these parameters differed across sex, age, and competition events. Our results indicated that jump height was significantly associated with sex and age, yet other CMJ variables (e.g., modified reactive strength index, peak relative propulsive power, peak relative propulsive force, and relative net propulsive impulse). This discrepancy likely reflects the unique methodological design: age was a significant factor only for jump height, whereas for other CMJ variables it did not reach statistical significance. Furthermore, body mass did not emerge as a significant covariate for any of the CMJ metrics we evaluated.

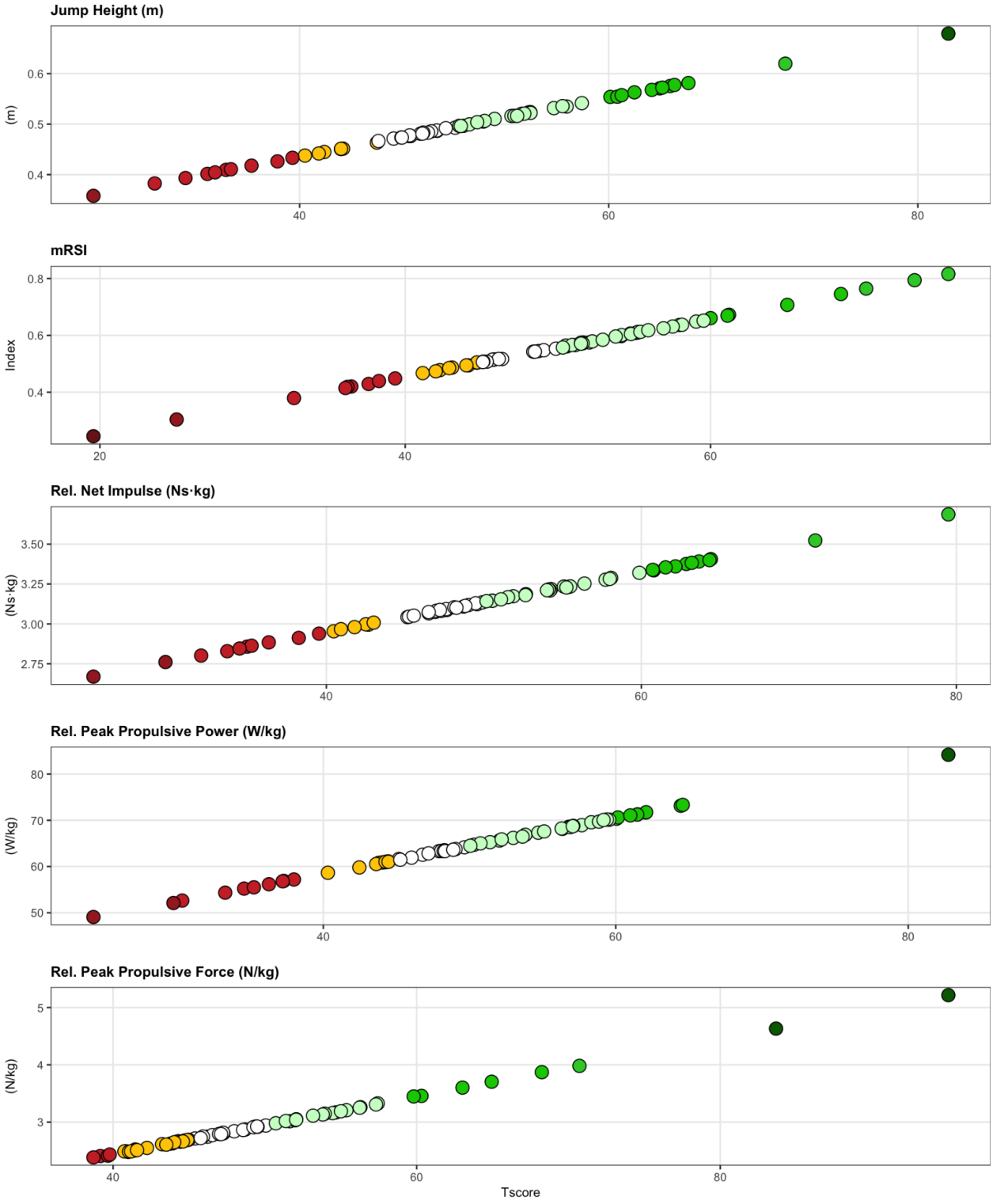
We acknowledge that wushu, as a martial art, has distinct physical demands when compared to other sports such as sprinting and high jumping. Nevertheless, referencing studies on track and field athletes (Philpott et al., 2021) provides useful historical context and points of comparison for vertical jump data collection and analysis. Sprint athletes, for example, tend to generate higher horizontal force rather than vertical force (Morin et al., 2011), while high jumpers share a more similar emphasis on vertical force production—akin to wushu athletes who rely on explosive aerial maneuvers. In comparing these findings, we observed that our male wushu athletes achieved mean jump heights (0.449 ± 0.058 m) similar to the ranges reported for sprinters (0.464 ± 0.061 m) and significantly higher than the rugby forwards (McMahon et al., 2022). Such cross-sport comparisons underscore the robust jumping capabilities of wushu athletes, potentially reflecting their frequent training in aerial skills and acrobatic routines.

Interestingly, our ANCOVA results indicated that while sex and age significantly influenced jump height, competition events did not. We suspect that although certain wushu events (e.g., Chang Quan versus Nan Quan) emphasize different stylistic and technical elements, overall CMJ demands may be sufficiently similar across sub-disciplines to yield comparable jump performances. For other CMJ metrics—such as mRSI, relative net impulse, and peak force outputs—age and body mass were not significant covariates, suggesting these performance measures are more consistently influenced by neuromuscular factors rather than anthropometric or maturational differences.

Taken together, these findings serve as a foundational reference for coaches and practitioners in the wushu community. Establishing normative benchmarks enables more targeted training prescriptions and helps identify athletes who might benefit from specific interventions to optimize

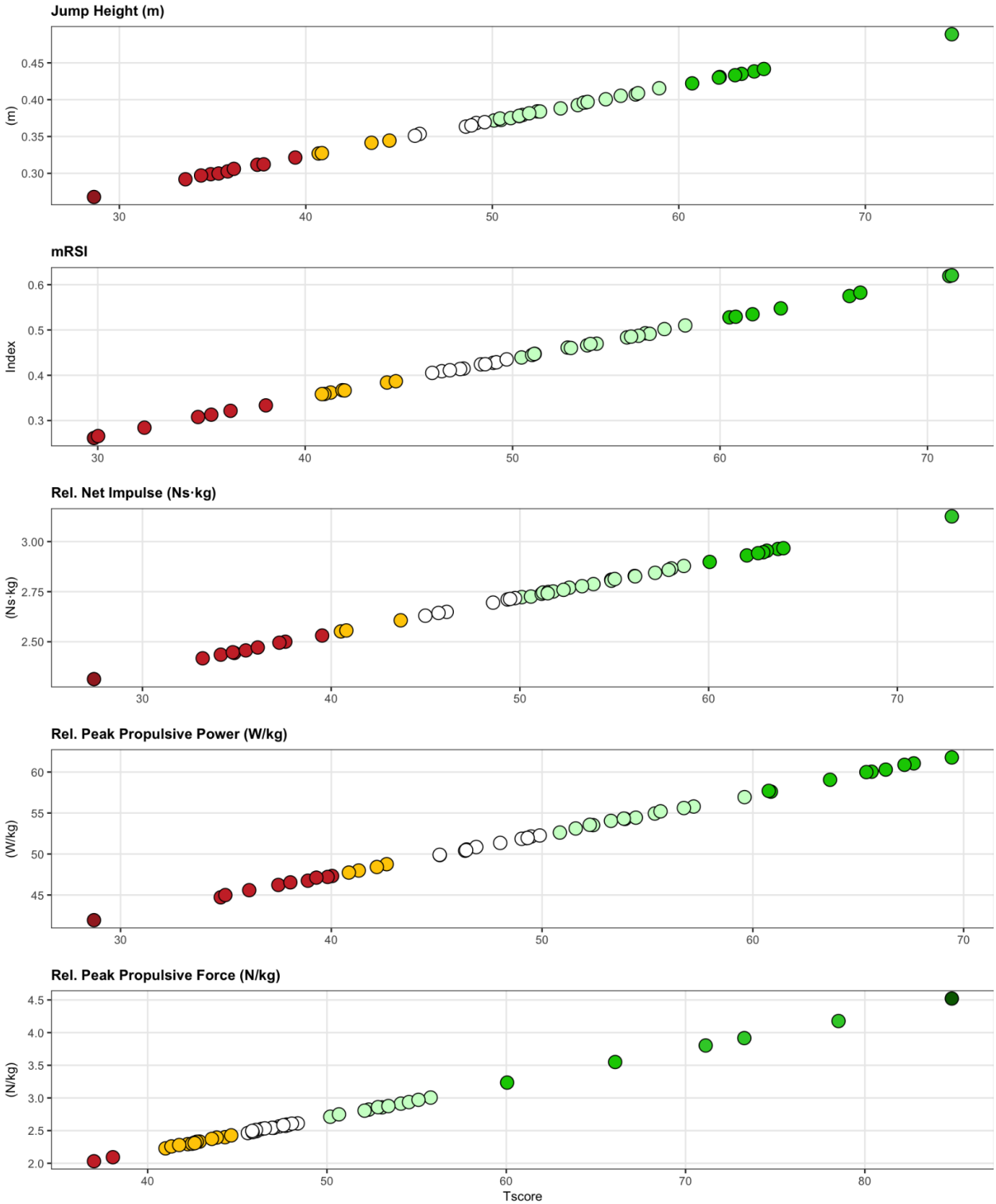
jump performance and reduce injury risk. However, our sample was limited to mid- to late-adolescence through early adulthood (16–23 y), which may not capture maturational differences outside this range. Caution is therefore warranted when generalizing to athletes of other nationalities, technical levels, or age brackets.

Figure 1. T-score vs. Countermovement Jump (CMJ) variables in male wushu athletes.



Note: Each panel shows a CMJ metric—jump height (m), modified reactive strength index (mRSI), relative net impulse (Ns·kg), peak relative propulsive power (W/kg), and peak relative propulsive force (N/kg)—plotted against T-score classifications (x-axis). Colored markers correspond to performance tiers ranging from Poor (red/orange) to Excellent (green), based on the normative data presented in Table 3.

Figure 2. T-score vs. Countermovement Jump (CMJ) variables in female wushu athletes



Note: Each panel shows a CMJ metric—jump height (m), modified reactive strength index (mRSI), relative net impulse (Ns·kg), peak relative propulsive power (W/kg), and peak relative propulsive force (N/kg)—plotted against T-score classifications (x-axis). Colored markers correspond to performance tiers ranging from Poor (red/orange) to Excellent (green), based on the normative data presented in Table 4.

Future research should (i) extend normative datasets across a wider age spectrum, ideally stratified by biological maturation stage, and (ii) examine how wushu-specific event demands interact with growth trajectories and injury-risk profiles in more diverse cohorts. Lastly, practitioners should be aware that different field devices use distinct algorithms to estimate jump height. In particular, flight-time systems such as jump mats, photo-cell arrays, and smartphone applications (e.g., MyJump2) typically overestimate countermovement-jump height by ≈ 2–3 cm

when compared with force-platform calculations (Montalvo et al., 2021). When benchmarking athletes against the normative values reported here, we therefore recommend subtracting 2–3 cm from heights obtained with these flight-time devices—or applying the device-specific correction equations published by Montalvo and colleagues.

5. Conclusions

This study provides relevant normative CMJ data tailored to wushu athletes, representing a first step in benchmarking performance metrics for this evolving sport. Our findings highlight the importance of sex- and age-based considerations for jump height, while noting that competition events appear to have limited influence on several other performance indicators. By promoting further exploration and comparison across various sports, age categories, and skill levels, we ultimately aim to deepen our collective understanding of vertical jump performance and its role in competitive success and athlete well-being.

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