Multi-Planar Jump Performance in Speed Skating Athletes: Investigating Interlimb Differences in an Asymmetrical Sport

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Abstract: Elite speed skaters are exposed to asymmetric lower limb loading consequent to the unidirectional turns inherent to the sport. This presents a unique model to study the effects of sport-specific loading on interlimb differences in mechanical muscle function. This study, therefore, examined baseline interlimb asymmetries in multi-directional jump tests in elite speed skaters using a cross-sectional design. Thereafter, participants were monitored longitudinally using the bilateral countermovement jump (CMJ) to quantify interlimb differences in mechanical muscle function throughout a competitive season. Pre-season baseline testing included a single leg lateral jump (JumpLat) and a single leg forward horizontal jump (JumpHorz) attached to a robotic linear position encoder, along with a bilateral CMJ on a dual force plate system. From baseline, CMJ monitoring was conducted throughout the 24-week competitive season. Within-limb changes in right vs left CMJ concentric impulse (CMJCon) and eccentric deceleration impulse (CMJEcc) were assessed using a linear mixed effects model. No systematic interlimb differences were found at baseline (p = 0.33–0.98) and the between-test agreement in limb dominance was poor (Kappa = −0.17–0.33). Furthermore, there were no time effects observed for interlimb differences in CMJCon (fixed effect = 0.01 N*s) and a small decrease in CMJEcc (fixed effect = −0.35 N*s, p = 0.01). These data suggest that even in a sport with asymmetrical loading, interlimb differences in mechanical output remain stable at the group level. However, changes occurring at the individual athlete level may be occurring that are meaningful for performance and injury.

Keywords: vertical jump; unilateral jump; horizontal jump; monitoring; ratio; limb dominance; maximal power test

1. Introduction

Bilateral asymmetry testing is often used to assess athletes after injury [1–5], but the effect of training on interlimb asymmetries in non-injured athletes remains ambiguous [6,7]. Longitudinal analysis of athletes participating in sports with asymmetrical loading patterns, such as long track speed skating, can provide a unique model to elucidate the effects of training on bilateral asymmetries. Additionally, characterizing interlimb asymmetries in skating sports may provide an important benchmark of comparison for athletes who sustain injuries.

Bilateral strength asymmetry testing, including interlimb assessments of mechanical power, are often conducted with variations of unilateral and bilateral jump testing by nature of the high reliability, feasibility, and practicality [8–12]. With widespread use of jump testing in sports performance settings, a natural question arises as to whether jump derivatives can be used to identify interlimb differences in mechanical muscle function. Although jump tests have shown promise in detecting limb strength impairments after
lower body injuries [1,3–5], research examining the relationship between jump asymmetries and performance or injury risk in non-injured athletes is inconclusive [6,7].

Interlimb jump asymmetries show poor agreement and high variation across test sessions and jump protocols in team sport athletes [13,14]. However, these studies have commonly quantified interlimb differences using an asymmetry index (AI) calculation, which tends to increase statistical variation [15] and aggregate measurement error [16]. The scientific evidence examining the relationship between jump asymmetries, sport performance and sport injury has also been limited by a lack of longitudinal research in elite athletes, with a relatively greater focus on team sport athletes that are not characterized by asymmetrical loading per se. The influence of asymmetrical loading, inherent to sports such as long track speed skating, has not been studied in the context of interlimb asymmetries in mechanical muscle function.

Long track speed skaters skate with only left turns using a leftward leaning body position to resist centrifugal forces. Both limbs are used for propulsion, but the right limb push is characterized by longer ice contact times and more sustained contractions to support the mass of the athlete and resist external forces [17]. This contributes to higher intramuscular forces, increased blood flow occlusion, and asymmetrical muscle oxygenation (right > left) throughout the race [18,19]. Conversely, modelling has shown that the left limb produces a higher instantaneous peak power output with shorter contact times during the turn phase [17].

Speed skaters have also been shown to incur 50–100% greater weekly training load than team sports such as field hockey or soccer [20], and present with interlimb asymmetries in bone mineral content and isometric knee extensor strength [21–23]. Similarly, structural asymmetries in pelvic orientation in a sample of skating athletes has been attributed to sport-specific asymmetrical loading and laterality within the skating stride [24]. To robustly assess jump asymmetry, a battery of tests which include sport-specific unilateral and bilateral movements has been recommended [25,26]. Recently, single leg lateral (Jump<sub>Lat</sub>) and horizontal (Jump<sub>Horz</sub>) jump tests were developed to simulate speed skating movement patterns, demonstrating high reliability and predictive validity in elite speed skaters [27]. However, it is unclear whether systematic interlimb differences in mechanical muscle function exist in speed skaters during jump testing, and how skating (i.e., asymmetric loading) influences interlimb function over a competitive season. Thus, the purpose of the present study is to: (1) assess systematic interlimb differences in a group of elite speed skaters using a battery of jump tasks (countermovement jump–CMJ, Jump<sub>Lat</sub>, Jump<sub>Horz</sub>); (2) compare limb dominance between tests; and (3) examine within-limb changes in CMJ concentric impulse (CMJ<sub>Con</sub>) and eccentric deceleration impulse (CMJ<sub>Ecc</sub>) throughout a competitive season.

2. Materials and Methods

2.1. Subjects

For cross-sectional baseline testing, long track speed skaters (n = 22; male: n = 12, female: n = 10) volunteered to participate. Subjects ranged from highly trained sub-elite athletes competing at the national level to elite athletes competing internationally at World Cup events. In the longitudinal study, athletes of the same performance level from short track (n = 6; males: n = 2, females: n = 4) and long track (n = 26; males: n = 18, females: n = 8) who completed regular CMJ monitoring and had accumulated >8 testing days throughout the season volunteered to have data included. This dataset was used for statistical analysis and included 1065 individual jump trials and 355 individual test sessions between the 32 participants. Characteristics of the subjects are presented in Table 1. To present within-limb changes in CMJ impulse at the individual level; this sample was further filtered to include the 20 participants that completed >10 testing days throughout the season. This choice was made to increase the strength of the analysis and the generalizability of the results, which also resulted in a more concise and clear visualization of the results. Athletes with injuries that limited maximal exertion jump testing were excluded. Participants
provided written informed consent before participating, which was approved by the Conjoint Health Research Ethics Board at the University of Calgary (CHREB 20-1751).

Table 1. Subject characteristics (mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
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<tbody>
<tr>
<td>Cross-sectional Analysis</td>
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<td></td>
</tr>
<tr>
<td>n</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Age (yrs.)</td>
<td>21.8 ± 1.4</td>
<td>22.8 ± 2.3</td>
</tr>
<tr>
<td>Body Mass (kg)</td>
<td>82.4 ± 6.3</td>
<td>64.6 ± 3.4</td>
</tr>
<tr>
<td>Longitudinal Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>Age (yrs.)</td>
<td>22.0 ± 1.4</td>
<td>22.3 ± 2.5</td>
</tr>
<tr>
<td>Body Mass (kg)</td>
<td>81.1 ± 2.2</td>
<td>63.9 ± 2.5</td>
</tr>
</tbody>
</table>

2.2. Procedures

Each test session was conducted following a scheduled rest day and prior to any other sport-specific training. All athletes were familiarized with the test protocols prior to data collection as a component of regular testing/monitoring, and testing was conducted by a certified strength and conditioning specialist. For baseline testing, athletes performed three jump protocols (Jump\textsubscript{Lat}, Jump\textsubscript{Horz}, CMJ) within a 7-day period during the pre-season. Longitudinal CMJ monitoring was conducted from the pre-season to the end of the competitive season according to the training and competition schedule.

2.3. Jump\textsubscript{Lat} and Jump\textsubscript{Horz} Protocols

A commercial robotic resistance device (1080 Sprint device, 1080 Motion, Lidingö, Sweden) that uses a servo motor (2000 RPM OMRON G5 Series Motor; OMRON Corporation, Kyoto, Japan) was used to conduct the single leg multi-planar jump testing protocol (sampling frequency = 333 Hz). Unpublished measurement errors obtained from the manufacturer were as follows: velocity error = ±0.5%, distance error = ±5 mm, force error = ±4.8 N [28]. Subjects attached a waist-borne harness to the cable of the robotic resistance device. Jumps were performed against a load of 10 N (i.e., the minimum load required to maintain proper flywheel function).

For Jump\textsubscript{Lat}, participants initiated the jump from a self-determined skating position and were permitted to use an arm swing. A strong verbal cue was used, and participants were instructed to “jump laterally as far as possible, landing on both legs“. Each jump was initiated from a 30-degree angled slant board set 5 m away from the robotic device (Figure 1A), and three maximal effort trials were performed on each limb (alternating with each jump). The Jump\textsubscript{Horz} test was conducted in the same manner as the Jump\textsubscript{Lat} except that the athletes projected their body centre of mass forward (Figure 1B) and were instructed to “jump horizontally as far as possible, landing on both legs“. Position and time were collected and processed, using the robotic resistance device software (TrainitTest software Version 3—1080 Motion) to obtain the peak velocity of each jump, and exported for further analysis.

2.4. Bilateral CMJ

Subjects performed three maximal CMJ trials at a self-selected depth with their hands fixed firmly on the hips [3]. Subjects were directed to jump “as high as possible” and received a countdown of “3, 2, 1, jump!” prior to each trial. Any jump trials that did not fulfill these requirements were discarded and repeated. Vertical ground reaction forces (F\textsubscript{Z}) from the right and left limbs were measured simultaneously using a dual force plate system (ACP-O Force Platform, AMTI, Watertown, MA, USA) at a sampling frequency of 1000 Hz and recorded on a personal computer (MyoResearch Version 3.20, Noraxon, Scottsdale, AZ, USA). The velocity of the body centre of mass (BCM) was obtained as described by Jordan et al. [3] and used to define the phases within the jump. The eccentric
deceleration phase was defined as the interval between the maximum negative velocity to zero velocity, and the concentric phase was defined from zero velocity to the instant of jump takeoff [3]. The total impulse $F_z$ for the left and right limbs during each respective phase were exported and analyzed using a custom-built computer program (Matlab R 2022a, Mathworks, Natwick, MA, USA). A previous examination of within-subject reliability from an athlete population ($n = 109$) for the jump analysis described in this study demonstrated good coefficients of variation for the $CMJ_{Con}$ impulse (left = 3.32%, right = 3.79%) and the $CMJ_{Ecc}$ impulse (left = 5.06%, right = 5.61%) for athlete monitoring.

![Figure 1. Start position for the single leg lateral jump (panel (A), JumpLat) and the single leg forward horizontal jump (panel (B), JumpHorz).](image)

### 2.5. Statistical Analysis

The three-jump mean value was calculated for all outcomes measures and used in the statistical analyses that were conducted in R Studio Version 2.07.2 (R Version 4.2). Normality of the data was assessed through visual inspection of plots and histograms of the residuals for all variables and with a Kolmogorov–Smirnov test with the $\alpha$ level set to <0.05. Paired samples $t$-tests were used to assess interlimb differences in the peak velocity for the $Jump_{Lat}$ and $Jump_{Horz}$ and the impulse of $F_z$ for the CMJ eccentric deceleration and concentric phases. Limb dominance was established based on the maximum value between the left and right limbs, and Kappa coefficients were calculated to determine the consistency between tests [29]. As per Viera and Garrett [30], coefficients were interpreted as follows: $\leq 0 = \text{poor}, 0.01–0.20 = \text{slight}, 0.21–0.40 = \text{fair}, 0.41–0.60 = \text{moderate}, 0.61–0.80 = \text{substantial}, \text{and} 0.81–0.99 = \text{almost perfect}$. To detect interlimb changes in CMJ impulse throughout the season, linear mixed effects models (R Version 4.2, ‘lme4’ package) were fit with fixed effects for limb, time (in weeks), and the interaction between time and limb. Random effects were included for athletes, with limb (left and right) nested within the athlete to account for the repeated measurements throughout the season. Models were built individually for $CMJ_{Con}$ and $CMJ_{Ecc}$, and residuals met the appropriate assumptions. To present within-limb changes in impulse throughout a competitive season, scatterplots with a line of best fit were built using locally estimated scatterplot smoothing (R Version 4.2, ‘ggplot2’ package), with the standard error (SE) used to calculate the 80% confidence interval (CI).
3. Results

3.1. Cross-Sectional Analysis

No systematic differences ($p > 0.05$) were observed between the left and right limbs for peak velocity during $\text{Jump}_{\text{Lat}}$, $\text{Jump}_{\text{Horz}}$, or CMJ phase-specific impulses (Table 2, Figure 2). Kappa coefficients ranged from poor to slight agreement for all inter-jump comparisons of limb dominance (Table 3).

Table 2. Interlimb comparison (mean ± SD), mean difference (95% confidence interval) and paired sample $t$-test results ($p$) for jump outcome measures.

<table>
<thead>
<tr>
<th></th>
<th>Right</th>
<th>Left</th>
<th>Mean Difference (95% CI)</th>
<th>$p$</th>
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<tbody>
<tr>
<td>Peak Velocity (m/s)</td>
<td></td>
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<td></td>
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<tr>
<td>$\text{Jump}_{\text{Lat}}$</td>
<td>2.65 ± 0.22</td>
<td>2.64 ± 0.21</td>
<td>0.01 (−0.06 to 0.05)</td>
<td>0.77</td>
</tr>
<tr>
<td>$\text{Jump}_{\text{Horz}}$</td>
<td>3.34 ± 0.38</td>
<td>3.36 ± 0.38</td>
<td>−0.02 (−0.03 to 0.07)</td>
<td>0.33</td>
</tr>
<tr>
<td>Impulse (N*s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{CMJ}_{\text{Con}}$</td>
<td>209 ± 46</td>
<td>209 ± 39</td>
<td>0 (−26 to 25)</td>
<td>0.98</td>
</tr>
<tr>
<td>$\text{CMJ}_{\text{Ecc}}$</td>
<td>127 ± 30</td>
<td>124 ± 24</td>
<td>3 (−20 to 13)</td>
<td>0.65</td>
</tr>
</tbody>
</table>

$\text{Jump}_{\text{Lat}}$, single leg lateral jump; $\text{Jump}_{\text{Horz}}$, single leg horizontal jump; $\text{CMJ}_{\text{Con}}$, countermovement jump concentric phase; $\text{CMJ}_{\text{Ecc}}$, countermovement jump eccentric deceleration phase.

Figure 2. Box and whisker plots of interlimb dominance in jump performance under different conditions: (A) $\text{Jump}_{\text{Lat}}$, single-leg lateral jump; (B) $\text{Jump}_{\text{Horz}}$, single-leg horizontal jump; (C) $\text{CMJ}_{\text{Con}}$, countermovement jump concentric phase; (D) $\text{CMJ}_{\text{Ecc}}$, countermovement jump eccentric deceleration phase.

Table 3. Agreement in limb dominance between jump conditions.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Kappa Coefficient</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Jump}<em>{\text{Lat}}$−$\text{Jump}</em>{\text{Horz}}$</td>
<td>−0.17</td>
<td>Poor</td>
</tr>
<tr>
<td>$\text{Jump}<em>{\text{Lat}}$−$\text{CMJ}</em>{\text{Con}}$</td>
<td>0.03</td>
<td>Poor</td>
</tr>
<tr>
<td>$\text{Jump}<em>{\text{Horz}}$−$\text{CMJ}</em>{\text{Con}}$</td>
<td>0.21</td>
<td>Slight</td>
</tr>
<tr>
<td>$\text{CMJ}<em>{\text{Con}}$−$\text{CMJ}</em>{\text{Ecc}}$</td>
<td>0.33</td>
<td>Slight</td>
</tr>
<tr>
<td>$\text{CMJ}<em>{\text{Ecc}}$−$\text{Jump}</em>{\text{Lat}}$</td>
<td>−0.01</td>
<td>Poor</td>
</tr>
</tbody>
</table>

$\text{Jump}_{\text{Lat}}$, single-leg lateral jump; $\text{Jump}_{\text{Horz}}$, single-leg horizontal jump; $\text{CMJ}_{\text{Con}}$, countermovement jump concentric phase; $\text{CMJ}_{\text{Ecc}}$, countermovement jump eccentric deceleration phase.
3.2. Longitudinal Analysis

No interaction was found for CMJ_{Con} between limb and time. There was no effect of limb on CMJ_{Con} ($p = 0.35$), or time ($p = 0.66$) from baseline to the end of the season. For CMJ_{Ecc}, a significant interaction was found between time and limb ($X^2 = 4.77$, df = 644, $p = 0.03$). The left limb declined to an extent larger (change = $-8.40$ N*s, $p = 0.01$) than the right limb (change = $-5.28$ N*s, $p = 0.01$) from baseline to end of season. Individual variation in CMJ_{Con} and CMJ_{Ecc} within-limb impulses for the subset of the original sample that completed >10 monitoring sessions is presented in Figures 3 and 4.

Table 3. Agreement in limb dominance between jump conditions.

<table>
<thead>
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<th>Comparison</th>
<th>Kappa Coefficient</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>JumpLat-JumpHorz</td>
<td>-0.17</td>
<td>Poor</td>
</tr>
<tr>
<td>JumpLat-CMJCon</td>
<td>0.03</td>
<td>Poor</td>
</tr>
<tr>
<td>JumpHorz-CMJCon</td>
<td>0.21</td>
<td>Slight</td>
</tr>
<tr>
<td>CMJCon-CMJEcc</td>
<td>0.33</td>
<td>Slight</td>
</tr>
<tr>
<td>CMJEcc-JumpLat</td>
<td>-0.01</td>
<td>Poor</td>
</tr>
</tbody>
</table>

JumpLat, single-leg lateral jump; Jump Horz, single-leg horizontal jump; CMJ Con, countermovement jump concentric phase; CMJ Ecc, countermovement jump eccentric deceleration phase.

Figure 3. Within-limb variation in countermovement jump concentric phase impulse for ($n = 20$) participants that completed >10 monitoring sessions in-season. Shaded area represents confidence interval set to a level of 0.8.
4. Discussion

The present study examined interlimb differences in mechanical muscle function in elite speed skaters during sport-specific bilateral and unilateral jump testing. Given asymmetrical loading conditions in speed skating that have been shown to result in morphological and strength asymmetries, this study contributes to our understanding of how training affects interlimb asymmetries in jump testing. It also characterizes bilateral asymmetries in lower limb mechanical muscle function in non-injured skaters, which may serve as a benchmark in injured athletes given the frequent use of jump testing to detect insufficient rehabilitation.

Contrary to our expectation, systematic interlimb differences were not detected within our jump protocols (JumpLat, JumpHorz, CMJ), and limb dominance was inconsistent between tests (c.f. Tables 2 and 3). There also appeared to be no change in the left vs. right CMJCon impulse and a small time effect for CMJEcc impulse (decreasing eccentric deceleration impulse) along with high inter-subject and interlimb variance during the competitive season. Given the body of literature that has observed high variability in both the magnitude and direction of asymmetries, such findings may be expected [31–34]; however, our results conflict with our initial expectations and the results of other studies that demonstrated a certain degree of laterality in speed skaters [21–24]. It is unclear whether our results are specific to the variability and limitations of jump testing or a lack of laterality in these athletes, given that our study did not measure anatomical outcomes or strength using conventional dynamometry.

Thus, in accordance with previous work on team sports [35], we recommend that interlimb jump differences should be analyzed at the individual level in speed skating.

Figure 4. Within-limb variation in countermovement jump eccentric deceleration phase impulse for (n = 20) participants that completed >10 monitoring sessions in-season. Shaded area represents confidence interval set to a level of 0.8.
athletes. Practitioners examining the presence of chronic adaptations related to the sport of speed skating may be better served utilizing tests such as clinical assessments [24], anthropometry [36], or dynamometry to isolate specific muscle groups [37]. It is important to note that the JumpLat and JumpHorz testing was only conducted during pre-season data collection, which may have limited our ability to detect the emergence of sport-specific asymmetries throughout the season.

The CMJ testing, on the other hand, was collected regularly throughout the 24-week season as a part of routine athlete monitoring. In contrast to unilateral jumping, asymmetries during the bilateral CMJ are thought to be related to variations in limb loading between the lower limbs, pelvis, and trunk [25,38]. The utility of the bilateral CMJ in monitoring interlimb differences is controversial, though much of the research is limited by a lack of repeated measures and reliance on ratio data [31,39]. Moreover, the CMJ is a common performance test, with demonstrated value for assessing neuromuscular readiness [40] and guiding the return to play process after injury [1]. Athletes from skating sports have been presented with changes in both orientation and structure across the lumbopelvic region [21,24,41], which may alter phase specific CMJ impulses between limbs. Thus, quantifying longitudinal changes throughout a competitive season may be of interest to practitioners working with skating populations.

Statistical modelling showed that CMJCon impulse did not change meaningfully in our sample of speed skaters from baseline to end of season. CMJEcc impulse decreased throughout the season, with changes of −8.4 N*s and −5.3 N*s between the left and right limbs, respectively. Considering a CV of ~5% for CMJEcc, this change would seem meaningful for an athlete producing a 100 N*s impulse on each limb. Speed skating is predominated by isometric and concentric muscle actions, and it is plausible that the increasing proportion of training hours spent on-ice throughout the season could have contributed to this phenomenon. Future work may utilize dynamometry to examine within-season changes in eccentric strength of the lower limbs in these athletes more conclusively. Nevertheless, we observed an interlimb change of 3.12 N*s which favored the right limb, which would fall below the CV values reported above. This suggests that interlimb impulse for either phase of the CMJ does not change meaningfully in speed skaters during the competitive season. Visual inspection of Figures 3 and 4 lend credence to this conclusion, where it seems that athletes tended to present similarly (either symmetrical or asymmetrical) throughout the 24-week season.

This conflicts with the work of Bishop et al., who observed limb dominance to be highly variable within a single season in samples of soccer athletes across two studies [13,14]. However, Bishop et al. had a reduced test frequency compared to the present study, thus making it difficult to infer whether the stable interlimb status observed in the present study can be attributed to the constraints of speed skating or the increased frequency of testing. In either case, our results highlight the necessity of analyzing interlimb and intralimb changes at the individual level in speed skaters. Practitioners may also consider monitoring the mechanical muscle function of each limb separately rather than relying on ratio data such as an AI. Representing an illustrative example, subject #12 (c.f. Figure 3) demonstrated a negative trend in CMJCon impulse for the right limb towards the end of the season, resulting in reduced overall jump performance; however, this was also associated with reduced asymmetry. Practitioners monitoring only an AI may falsely interpret this as a positive training adaptation rather than a reduced mechanical output. Similarly, while the interlimb asymmetries were negligible at the group level, individual baselines highlight athletes with elevated asymmetries that may be relevant from a training, injury, or performance perspective.

Interestingly, there were several instances of persistently elevated interlimb differences for the CMJEcc (c.f. Figure 4; athletes #1, #6, and #7). While not a part of the original aim of this study, a post hoc anecdotal survey revealed that a number of these athletes had a documented history of lumbopelvic injuries. Although speculative, future work may seek to investigate whether systemic injuries to the hip and low back complex influence loading
during CMJ Ecc in various skating populations. Conflicting evidence exists regarding the impact of previous injury on CMJ force-time variables, but it is likely that the lateral dominance of skating imposes differential demands on the lumbopelvic complex than in team sport athletes.

There are limitations in this study that should be kept in mind when interpreting our results. First, assessment of the JumpLat and JumpHorz were only conducted during the pre-season baseline testing, and results may have differed had these protocols been used continuously in conjunction with the CMJ as on-ice training hours accumulated. Second, CMJ testing was used as part of routine athlete monitoring and the frequency of testing was not strictly controlled. Finally, training and injuries were not monitored; thus, it was impossible to determine what contributed to the individual, within-limb, time-course change in CMJ impulse displayed over the course of the season. Future research may consider examining interlimb differences in mechanical muscle function in skating athletes with previous injuries as a marker of sufficient rehabilitation and readiness to perform.

5. Conclusions

We did not find systematic interlimb differences in mechanical muscle function during multi-planar jumping in elite speed skaters. Furthermore, the right vs. left lower limb function was relatively stable during the competition season. Practitioners deploying these protocols with athletes are advised to analyze data at the individual athlete level, monitor within-limb changes rather than ratios, and ensure that sufficient data is collected to establish reliable benchmarks in the event of injury.

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Conflicts of Interest: The authors declare no conflict of interest.

References


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