

Optimizing performance in floorball: A comprehensive analysis of ankle plantar-flexor muscle strength components

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Abstract

Problem Statement: High-intensity movements place a substantial mechanical load on the ankle joint, increasing the risk of injury to the ankle complex if the musculoskeletal system is not adequately prepared. Currently, there is limited evidence regarding whether unilateral ankle plantar flexor (PF) strength components provide an accurate measure of an athlete's single-limb readiness for plyometric activities and the potential risk of ankle complex injuries. **Purpose:** The primary aim was to assess differences in the unilateral reactive strength index (RSI) and isometric ankle muscle strength among male floorball players across age groups, playing positions, and competitive levels. The secondary aim was to determine strength benchmarks and to explore the relationship between relative PF strength and the RSI. **Methods:** Seventy-six athletes (under 17 years [U17]: $n = 27$; under 20 years [U20]: $n = 23$; and 20+ years: $n = 26$) performed a unilateral foot-ankle 10/5 rebound jump and isometric seated PF strength test. Strength levels were categorised using the T-scores. **Results:** The unilateral RSI and relative PF strength significantly differed across the age groups ($p < .05$, $\eta^2 = .088-.120$) and playing levels ($p < .001$, $d = 0.87-1.59$), but not by playing position. Thirteen athletes had a poor RSI and poor PF strength in both measures, while twelve had good RSI, but fifteen had good relative PF strength. Unilateral relative PF strength associated with the RSI ($r = .403-.593$, $p < .01$), with weaker athletes demonstrating a lower average power and jump height. **Conclusions:** These findings highlight differences in unilateral strength components, suggesting that athletes with a stronger ankle PF tend to perform jumps better. Younger and lower-level floorball players may benefit from targeted ankle strengthening to enhance performance and reduce injury risk.

Keywords: sport performance, team sports, benchmarking, decision-making, neuromuscular readiness

Introduction

In high-intensity, invasive team sports such as floorball, the maximal and reactive strength qualities of the lower limb muscles are crucial for performance efficiency. Muscle strength is strongly associated with improvements in force-time characteristics and can differ between individuals based on anthropometry, chronological age, sport, playing level, and strength training experience (Suchomel et al., 2016a). Maximal lower limb muscle strength is traditionally assessed through dynamic tests, indicating a one-repetition maximum (1RM) (Nuzzo et al., 2008). However, isometric tests are often used in practice, providing a safer, less fatiguing, and practical alternative, especially when assessing the maximal strength of single-joint muscle groups (Lum et al., 2020). Maximal muscle strength refers to the ability to produce the maximal voluntary force against an external object or resistance; it is influenced by both neural and muscular factors (Zatsiorsky & Kraemer, 2005). In contrast, reactive strength is a neuromuscular quality that indicates the subject's capability to effectively utilise the fast muscle stretch-shortening cycle (SSC < 250 ms) (Suchomel et al., 2016b) and the ability of the musculotendinous unit to rapidly transition from eccentric (stretching) to concentric (shortening) contractions (Southey et al., 2023). Because floorball requires repeated and rapid force production for the execution of technical and tactical elements, rebound jumps are an effective way to assess the reactive strength index (RSI), which is the ratio of the jump height (JH) to the contact time (CT; Flanagan et al., 2008). Rebound jumps, which are primarily ankle dominant, have similar mechanical demands to sprinting; hence, athletes must have an optimal level of movement pattern rhythm, limb stiffness, and eccentric strength for force development (Xu et al., 2025). Therefore, both muscle qualities are important for performance efficiency, highlighting the need for targeted strengthening interventions and assessment tools for team sport athletes.

Reactive and maximal isometric strength have demonstrated significant associations with acceleration (Vecbērza et al., 2025), change of direction (Kozinc et al., 2021), and maximal sprint speed in team sports (Jarvis et al., 2022). Previous studies have reported that lower limb muscle strength deficits contribute to a decrease in performance or an increase injury risk (Mason et al., 2022), particularly in the ankle plantar flexors

(PF) (Green & Pizzari, 2017). The ankle PF, including the lateral and medial gastrocnemius and soleus, is the main ground reaction force generator in the propulsive phase (Pandy et al., 2021) and is the key joint for releasing power during jumping (Bobbett, 2001). Miller et al. (2024) reported no significant difference in absolute muscle volume between female and male sprinters in the lateral and medial gastrocnemius; however, they identified differences in the soleus. Therefore, soleus strength testing in sport has attracted considerable interest among practitioners (Lee et al., 2023; Rhodes et al., 2022), indicating an impact on running performance and injury risks, such as Achilles tendinopathy, strain injuries and ankle sprains (O'Neill et al., 2019, 2023). Green et al. (2020) indicated that the soleus is the most commonly injured calf muscle (84.6%). However, in floorball, Hagovská et al. (2024) reported a high prevalence of ankle pain (62.3%), partly due to the hardcourt surfaces and multidirectional movements, indicating possible deficits in ankle strength. As a result, the athlete is unable to perform the sport-specific fundamental movements effectively, which affects the dynamics and outcome of the game. These findings highlight the need for ankle PF strength assessment and monitoring as well as targeted injury prevention strategies in team sports. Although Beattie et al. (2017) reported a moderate association between bilateral strength qualities based on isometric mid-thigh pull and drop jumps (hip and knee joint dominant movements; $r = .302-.431, p \leq .05$), there is still a lack of evidence regarding unilateral strength levels of ankle joint-dominant assessments across age groups, playing positions, and/or performance levels. Therefore, we examined the force-generating capacity of the ankle complex to determine whether unilateral strength assessments provide more realistic and accurate information on neuromuscular efficiency.

As sports technology advances, practical neuromuscular assessments can indicate an athlete's readiness for high-intensity activities, providing coaches with information to inform decision-making (Janetzki et al., 2023). Although "readiness" is frequently associated with the psychological state and recovery from previous injuries, neuromuscular testing provides objective indicators of the readiness of the musculoskeletal system (Podlog et al., 2015). Thus, neuromuscular testing enables athletes to identify and avoid repeated or potential new injuries if their performance is poor or not at an optimal level. For example, a poor RSI emphasises deficits in neuromuscular control, such as prolonged eccentric and amortisation phases, resulting in a longer CT, an insufficient number of muscle-tendon units, and overall limb stiffness, all of which influence sprinting performance (Bishop et al., 2023; Jarvis et al., 2022). RSI performance thresholds can indicate that an athlete has a poor RSI (low reactive strength capability) and therefore is not prepared for moderate-intensity plyometric-based activities (e.g., jumping and sprinting) and must focus on developing strength and improving their jumping technique. A good RSI indicates a well-established or high-level reactive strength capability, and the athlete is prepared to perform high-intensity activities without the risk of overload or injury (Flanagan & Comyns, 2018). There is scientific evidence that strength levels differ between the genders, competitive levels, playing positions, and sports and are associated with physiological and match demands, but there is a lack of comprehensive analysis of the performance or kinetic variables that indicate neuromuscular readiness.

Floorball is a relatively new team sport, so the strength and conditioning of floorball players has been relatively under-researched. This lack of information had led to significant challenges for coaches and practitioners to physically prepare the athletes according to the requirements of the sport. There is a need for assessments of strength differences between age groups, playing positions, and performance levels to obtain more detailed information about possible individualisation strategies that could reduce the frequent risk of ankle injuries among floorball players (Liukkonen et al., 2024). Establishing normative data and benchmarks (target setting) is important for floorball practitioners to assess the musculoskeletal status, to address strength deficits, and to perform physical profiling. In sport, benchmarks are established by calculating T-scores, which provide an individualised value of an athlete's strength level relative to a cohort. According to Turner et al. (2019), the T-scores are an alternative to the Z-score. It is calculated by multiplying the Z-score by 10 and adding 50, and then divided into performance bands (e.g., extremely poor, very poor, poor, below average, average, above average, good, very good, and excellent). Cohort-specific normative data followed by data visualisation serves as an effective approach to determine physical readiness, jump execution strategies, training loads or prescriptions, and acute fatigue. Moreover, it is necessary to establish the benchmarks that reflect the force generation patterns (i.e., bilateral or unilateral) of athletes. This information could enhance decision-making regarding the neuromuscular readiness of athletes for sport-specific high-intensity activities.

The primary aim of this study was to evaluate differences across age groups, playing positions, and performance levels in the unilateral RSI and rebound jumps kinematic metrics of floorball players, including the JH, the CT, the flight time (FT), vertical stiffness (K_{vert}), the average power (AP), and relative ankle PF strength. The secondary aim was to identify poor and good strength readiness levels by calculating T-scores and the association between unilateral relative ankle PF strength, jumping performance, and kinematic variables. We tested two hypotheses: there are statistically significant differences between age groups and playing levels in the unilateral RSI and ankle PF strength (H1), and most floorball players have a low RSI, indicating that weaker athletes are less prepared for high-intensity activities (H2). We hope to provide crucial insights into the ankle PF neuromuscular readiness of floorball players for high-intensity plyometric activities based on isometric and reactive strength testing and data visualisation strategies. In addition, this study offers empirical contributions to the physical preparation and development strategies of athletes and encourages coaches and practitioners to regularly incorporate ankle complex strengthening methods into the training process. Moreover, the analysis of

unilateral strength and rebound jump kinematic metrics allows the examination of age- and sport-specific characteristics, as well as the impact of strength deficits on jumping performance. This study addresses a critical gap in the literature and provides practical tools for monitoring athlete performance. Therefore, adopting this holistic approach may positively impact informed decision-making by coaches by providing them with the opportunity to integrate appropriate training methods to enhance athlete performance.

Material and Methods

Participants

An *a priori* sample size estimation was performed using the G*Power software (version 3.1.9.6, Kiel, Germany) based on previous research by Doyle et al. (2021), which identified an average effect size ($d = 0.8$) between the senior (20+ years), under 17 years (U17), and under 20 years (U20) age groups. Based on the calculation, considering statistical power of 0.80 and an alpha error of 0.05, a minimum of 21 participants are required in each group (Faul et al., 2007). In total, the sample included 76 male floorball players (age: 18.9 ± 3.9 years; height: 180.0 ± 7.1 cm; body mass: 76.1 ± 9.9 kg; body mass index: 23.4 ± 2.5) from three Latvian first and higher division teams. All participants were subsequently categorised into age groups, U17 ($n = 27$), U20 ($n = 23$), and 20+ ($n = 26$); playing positions, including attackers ($n = 46$) and defenders ($n = 30$); and playing levels, namely highest league ($n = 42$) and first league ($n = 34$). The inclusion criteria were: (a) no reported musculoskeletal injuries in the past 3 months that could affect performance or overall physical and psychological health; (b) registered in the official Latvian Floorball Federation players register; and (c) aged 15–30 years old. Each participant signed a mutual written informed consent form prior to data collection. The study was approved by the University of Latvia Humanities and Social Sciences Ethics Committee (approval number 71-46/137) and was conducted following the principles set in the Declaration of Helsinki.

Procedure

A cross-sectional study design was used to investigate the unilateral RSI as a practical tool to assess and monitor subject readiness for plyometric activities. In addition, all results were compiled as normative data. The data were collected during the 2023/2024 and 2024/2025 regular seasons. The test procedures took place in natural settings (e.g., on a synthetic floorball surface, at the participants' training base and time). Before the testing, the participants completed a standard warm-up consisting of muscle activation, dynamic lower-limb stretching, and specific jumping exercises. Before data collection, each participant received standard instructions and performed two familiarisation trials with submaximal intensity. The MuscleLab infrared optical contact grid (Ergotest Technology, Porsgrunn, Norway) was used for the 10/5 foot–ankle rebound jump test, with data recorded using the MuscleLab Professional Software and then exported to Excel for further analysis. The maximal absolute isometric ankle PF strength was evaluated using a dynamometer (Peak Force, Mesquite, TX, USA).

Unilateral Foot–Ankle Rebound Jump Test

The unilateral foot–ankle dominant jumping strategy in the 10/5 repeated rebound jump test was used to determine the fast muscle SSC mechanism of each participant. The test has previously demonstrated high reliability (intraclass correlation coefficient [ICC] > .90, coefficient of variation [CV] = 12%; Tourillon et al., 2024). Baker et al. (2022) reported that the test is valid and reliable to monitor the RSI in adolescent male athletes. In the 10/5 rebound jump test, the participant executes a single countermovement jump immediately following consecutive and repeated jumps at a self-selected frequency to increase the JH while maintaining a minimal CT with the ground (Xu et al., 2024). Using an alternating limb strategy, each participant performed three trials with a 3-min recovery between the trials. The five jumps with the highest RSI from each limb's best trial were selected for further analysis, whereas the combined average value of both limbs was utilised for kinetic performance analysis. The RSI was calculated as the ratio of the JH to the CT using the following equation:

$RSI = \text{jump height (cm)} / \text{ground contact time (ms)}$

The spring-mass model was used to calculate K_{vert} , represented mathematically as follows:

$$K_{vert} = \frac{F_{max}}{\Delta y_c}$$

$$F_{max} = mg \frac{\pi}{2} \left(\frac{t_f}{t_c} + 1 \right)$$

$$\Delta y_c = F_{max} \frac{t_c^2}{m\pi^2} + g \frac{t_c^2}{8}$$

where F_{max} is the maximal ground reaction force and Δy_c is the vertical displacement of the centre of mass. F_{max} and Δy_c were determined from the subject's body mass in kilograms (m), flight time in seconds (t_f), contact time in seconds (t_c), and π (approximately 3.14159; Morin et al., 2005). The JH (h) was calculated from the FT by using the following equation, where t is the FT and g is gravity acceleration (9.81 m/s^2):

$$h = \frac{(t^2 \cdot g)}{8}$$

The AP in rebound jumps was calculated using the peak power (W) equation described by Sayers et al. (1999), where h is the JH (in cm) and m is the subject's body mass (in kg):

$$\frac{60.7\text{kg} + 45.3\text{m} - 2055}{m}$$

$$AP = \frac{m}{m}$$

All measurements were obtained in MuscleLab Professional Software, ensuring accuracy without using manual calculations to avoid possible errors.

Unilateral Isometric Ankle PF Strength Test

Unilateral tests allow to determine the strength characteristics of each limb, especially because most movement patterns occur with one limb. The maximal absolute isometric strength of the ankle PF was determined by using a dynamometer in the sitting position (i.e., 90° hip and 90°–110° knee flexion, but with the ankle in full available dorsiflexion; Lee et al., 2023). Unlike the standing position, performing the test in a seated position with knee flexion ensures isolated maximal force generation of the soleus while inhibiting force generation of the gastrocnemius (Ferris & Hawkins, 2020). A previous study showed that the seated position test has high test–retest reliability (ICC = .91; O'Neill et al., 2023). While wearing their usual training shoes, each participant placed the front of his metatarsal heads (plantar surface) of the tested lower extremity in the centre of the dynamometer sensor. The participant placed the heel of the plantar surface on the wood portion of the dynamometer, creating a full foot position. A non-elastic tape was placed over the participant's femoral epicondyles or distal thigh to avoid compressing the quadriceps tendon. To ensure a safer test, a soft foam pad was placed under the strap when it was at maximum tension. The participant placed the palms of his upper limbs crosswise over his shoulders, maintaining his upper body in an upright position, and was instructed not to move his upper body forward, sideways, or backwards; to raise his knee by flexing the hip joint; or to lift his body above the bench. Then, after receiving approval, the participant performed three maximal unilateral isometric plantarflexion contraction trials of 3–5 s with 3 min of recovery between each trial. The average absolute maximal PF strength (kg) of each limb's best effort was used for data analysis; it was normalised by the participant's body mass to determine the relative maximal isometric strength (kgF/kg).

Statistical Analysis

The performance data were compiled in Microsoft Excel and analysed using IBM SPSS Statistics 29 version: 29.0.0.0 (241) (IBM Corp., Armonk, NY, USA). The RSI and ankle PF strength data were collected categorised into the age groups (U17, U20, and 20+ years), playing position groups (attackers and defenders), and playing level groups (highest league and first league). The Shapiro–Wilk test was utilised to evaluate whether the data followed a normal distribution. Pearson correlation coefficients were calculated to determine the association between combined limb average relative PF strength and rebound jump performance and kinetic variables; they were classified as trivial (< .1), small (.1–.3), moderate (.3–.5), large (.5–.7), very large (.7–.9), or near perfect (> .9). An independent t-test was performed to determine differences in the unilateral RSI and kinetic variables between playing levels and positions; Cohen's *d* was used to assess the effect size, classified as trivial (< .2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0), or very large (2.0–4.0; Hopkins et al., 2009). One-way analysis of variance (ANOVA) followed by the Tukey test for post hoc test was used to compare the age groups. Eta squared (η^2) was used to determine the effect size for group variables, classified as small ($\leq .01$), medium ($.06 \leq \eta^2 \leq .13$), and large ($\geq .14$). All test results were statistically significant if $p < .05$ (Cohen, 1988). The standardised T-scores were utilised to identify the poor and good unilateral RSI and relative PF strength thresholds. The T-score (ranging from 20 to 80) method is a user-friendly and interpretable alternative to the Z-score. It is calculated by multiplying the Z-score by 10 and adding 50. The T-scores are useful for practitioners to identify benchmarks and to monitor an athlete's neuromuscular readiness (Lockie et al., 2018; McMahon et al., 2022).

Results

The Shapiro–Wilk test confirmed that all variables were normally distributed. Table 1 presents the lower limb combined average unilateral rebound jump kinetic variables (the RSI, the JH, the FH, the CT, K_{vert} , and the AP) and the absolute and relative ankle PF isometric strength.

Table 1. Performance and kinetic variables from the unilateral foot–ankle 10/5 rebound jump and isometric PF strength tests in football players ($n = 76$), categorised by age, playing position, and playing level.

	Age			Playing positions		Playing level	
Measure	U17 ($n = 27$)	U20 ($n = 23$)	20+ ($n = 26$)	Attackers ($n = 46$)	Defenders ($n = 30$)	Highest league ($n = 42$)	First league ($n = 34$)
<i>Unilateral 10/5 foot–ankle rebound jump test</i>							
RSI	48.32 ± 11.88	59.29 ± 12.35	55.50 ± 13.41	54.09 ± 12.49	54.10 ± 14.48	61.47 ± 11.49	44.98 ± 8.82
JH (cm)	12.63 ± 3.13	15.78 ± 3.93	14.59 ± 3.36	14.32 ± 3.52	14.15 ± 3.92	16.31 ± 3.27	11.71 ± 2.26
CT (ms)	262.52 ± 30.67	263.36 ± 27.79	263.47 ± 25.46	264.04 ± 28.79	261.67 ± 16.44	265.32 ± 27.92	260.37 ± 27.66
FT (ms)	294.03 ± 40.45	331.47 ± 42.14	322.76 ± 36.18	314.55 ± 42.27	316.16 ± 42.98	333.21 ± 40.58	292.92 ± 33.02

K_{vert} (kN/m)	16.63 ± 4.30	16.23 ± 3.20	17.51 ± 3.36	16.67 ± 3.88	17.03 ± 3.38	16.70 ± 3.64	16.95 ± 3.76
AP (W/kg)	18.19 ± 4.24	20.59 ± 4.32	19.18 ± 4.67	19.47 ± 4.39	18.93 ± 4.61	21.26 ± 4.36	16.78 ± 3.19
<i>Unilateral ankle PF isometric strength test</i>							
Absolute PF strength (kgF)	129.71 ± 17.02	144.91 ± 18.81	151.90 ± 17.00	143.13 ± 19.14	140.02 ± 20.93	148.97 ± 16.47	133.17 ± 20.26
Relative PF strength (kgF/kg)	1.77 ± 0.25	1.94 ± 0.24	1.90 ± 0.21	1.89 ± 0.23	1.84 ± 0.26	1.95 ± 0.22	1.76 ± 0.23

Note. The data are presented as the mean ± standard deviation. The ages groups are under 17 years old (U17), under 20 years old (U20), and 20+ years. Abbreviations: AP, average power; CT, contact time; FT, flight time; JH, jump height; K_{vert} , vertical stiffness; PF, plantar flexor; RSI, reactive strength index.

Figure 1 presented the unilateral RSI and relative PF strength of the age and playing level groups based on the T-scores. The athletes are categorised into three performance groups: a poor RSI (≤ 41.97) and relative ankle PF strength (≤ 1.61 kgF/kg); a good RSI (≥ 68.23) and relative ankle PF strength (≥ 2.12 kgF/kg); and a middle performance band with athletes who performed above the poorest score but did not exceed the good strength threshold, with an average RSI of 55.10 and an average relative PF strength of 1.87 kgF/kg. We found that the average unilateral RSI and relative ankle PF strength differed significantly among the age groups ($p < .05$). Post hoc comparisons identified significant differences between the U17 and U20 groups in the unilateral RSI ($p = .008$; Figure 1A) and ankle PF strength ($p = .038$; Figure 1C), but no significant differences between the U20 and 20+ age groups. Based on a one-way ANOVA, there was a significant medium age group effect on the unilateral RSI, $F(2, 73) = 4.976$, $p = .009$, $\eta^2 = .120$, and ankle PF strength, $F(2, 73) = 3.505$, $p = .035$, $\eta^2 = .088$. Independent t-tests revealed significant differences between the highest and first-league groups in the unilateral RSI ($p < .001$), with a large effect size ($d = 1.59$, 95% confidence interval [CI] 1.06–2.10, $p = .10$; Figure 1B), as well as in ankle PF strength ($p < .001$), with a moderate effect size ($d = 0.87$, 95% CI 0.40–1.35, $p = .82$; Figure 1D). There were no significant differences between the playing positions.

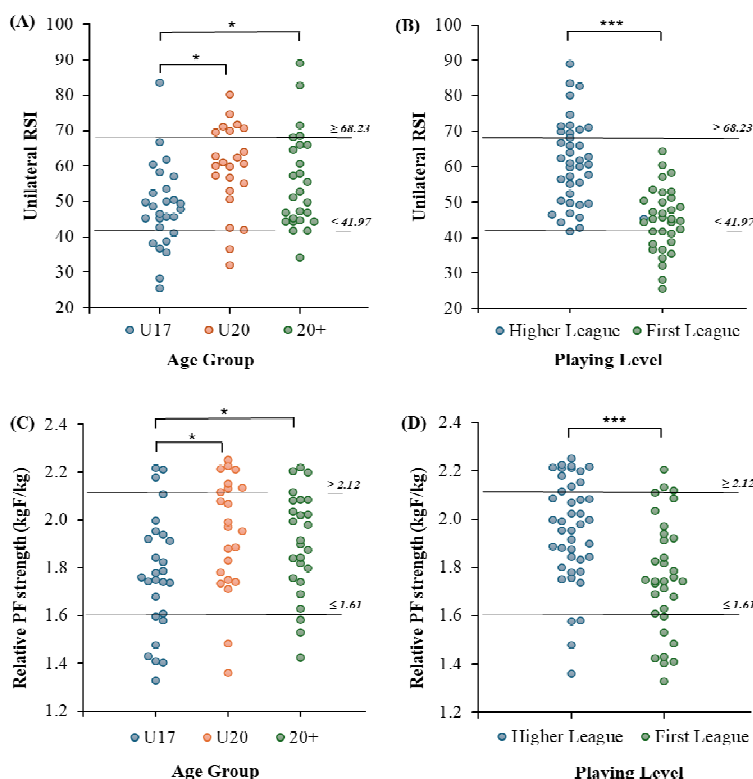


Figure 1. The unilateral combined limb average reactive strength index (RSI) and relative ankle plantar flexor (PF) strength variables for (A, C) the under 17 years (U17), under 20 years (U20), and 20+ years age groups, and (B, D) the playing level. The data are categorised into performance groups based on the T-scores performance bands (poor RSI ≤ 41.97 and relative ankle PF strength ≤ 1.61 kgF/kg; good RSI ≥ 68.23 and relative ankle PF strength ≥ 2.12 kgF/kg). * $p < .05$ and *** $p < .001$.

Association Between Maximal Relative Isometric Ankle PF Strength and Rebound Jump Performance and Kinetic Variables

Table 2 presents the Pearson correlation coefficients between relative PF strength and the RSI kinetic variables. Relative PF strength showed a significant large correlation with the RSI in the U17 ($r = .59, p < .01$) and 20+ ($r = .59, p < .01$) age groups, as well as with the playing positions and levels ($r = .40-.57, p < .01$). There was significant moderate to very large correlation between relative PF strength and the AP in rebound jumps across the age, playing position, and playing level groups ($r = .50-.73, p < .05$).

Table 2. Pearson correlation coefficients between relative isometric ankle plantar flexor strength and the RSI and rebound jumping kinetics variables across the age group, playing position, and playing level groups.

	Age			Playing position		Playing level	
Measure	U17 ($n = 29$)	U20 ($n = 23$)	20+ ($n = 24$)	Attackers ($n = 46$)	Defenders ($n = 30$)	Highest league ($n = 42$)	First league ($n = 34$)
RSI	.59**	.34	.59**	.57**	.56**	.40**	.49**
JH (cm)	.50**	.29	.44*	.43**	.48**	.30	.27
CT (ms)	-.13	.002	-.46**	-.23	-.10	-.09	-.38*
FT (ms)	.33	.14	.46*	.28	.54**	.31*	.14
K_{vert} (kN/m)	.04	-.26	-.14	.04	-.23	-.22	.08
AP (W/kg)	.67**	.50*	.73**	.59**	.72**	.56**	.60**

Note. The ages groups are under 17 years old (U17), under 20 years old (U20), and 20+ years. Abbreviations: AP, average power; CT, contact time; FT, flight time; JH, jump height; K_{verts} vertical stiffness; RSI, reactive strength index.

* $p < .05$. ** $p < .01$.

Discussion

Our primary aim was to assess differences in the unilateral RSI, rebound jumping kinematic metrics, and relative ankle PF strength across age, playing positions, and playing levels of floorball players that sought to indicate readiness level relative to the overall group. Several important findings were identified: (1) The U20 group had a higher unilateral RSI compared with the other age groups, primarily due to a higher JH and AP as well as relative ankle PF strength. (2) Thirteen athletes had a poor RSI and relative PF strength, 12 athletes had a good RSI, and 15 athletes had good relative PF strength. (3) There were significant correlations between relative PF strength and the AP in rebound jumps in all groups. Athletes with a weaker ankle PF showed a lower RSI, indicating that they may have been unprepared for high-intensity plyometric activities.

Foot-ankle maximal and reactive strength are two important neuromuscular indicators that show an athlete's level of readiness for high-intensity activity and their potential injury risk. Although previous studies have examined maximal strength based on isometric mid-high pulls and reactive strength based on drop jumps (Beattie et al., 2017), our study is one of the first to examine these qualities in the ankle PF, one of the main energy generators and absorbers during the running and jumping stance phase (Willer et al., 2024). We found significant associations between relative PF strength and the AP in rebound jumps ($r = .50-.73, p < .05$), and between relative PF strength and the JH in the U17, 20+, attackers, and defenders groups ($r = .43-.50$). We identified a negative correlation between relative PF strength and the CT in the 20+ age group ($r = -.46, p < .01$) and the first league group ($r = -.38, p < .05$). Based on the findings, we suggest that a higher RSI is associated with greater relative PF strength and improved AP, resulting in a higher JH.

Reactive and Maximal Strength Analysis Between the Groups

One of our main objectives was to determine differences in reactive and maximal strength between age, playing positions, and playing levels. Our data confirm age-related differences in the RSI, with younger athletes exhibiting a lower RSI than older athletes. The U20 group presented a higher unilateral RSI (59.29 ± 12.35) and relative PF strength (1.94 ± 0.24 kgF/kg), while the 20+ age group demonstrated higher absolute PF strength (151.90 ± 18.81 kg). Lee et al. (2023) reported similar results in rugby union players (1.86 ± 0.29 kgF/kg), but their sample had an older average age. RSI improvements with maturation result from enhanced movement competency, morphological adaptations, developments in mechanical properties, and improved neuromuscular capacity and motor control (Lloyd et al., 2012; Radnor et al., 2018). The lower RSI in the U17 age group may be attributed to reduced relative ankle PF maximal strength capacity, a lack of proper landing mechanics, and an immature muscle-tendon complex, which influence force-producing capabilities (Beattie et al., 2017). Of note, we identified strength component differences between the playing levels (RSI: $d = 1.59$; relative PF strength: $d = .87$), where the highest-league group showed significantly higher strength than the first-league group (ankle PF strength: 1.95 ± 0.22 vs 1.76 ± 0.23 kgF/kg; RSI: 61.47 ± 11.49 vs 44.98 ± 8.82). Likewise, Southey et al. (2023) reported significant differences between playing levels and emphasised that technical skills, maximal strength capacity, and training volume affect strength components. Our findings suggest that amateur athletes are more at risk for ankle complex injuries, consistent with a previous study (Asperti et al., 2017). Regarding the playing position, both attackers and defenders showed a similar RSI and relative PF strength, although a previous study

reported RSI differences between playing positions (Pehar et al., 2017). In floorball, defenders and attackers must execute the technical and tactical elements equally to allow effective transition between attacking and defending positions and vice versa. Most floorball teams follow a similar training plan, minimising potential differences between the playing positions.

Regarding the rebound jump kinetic variables, the participants had an average CT above the 250 ms threshold, indicating a slightly longer CT that theoretically reflects a fast SSC mechanism. However, due to jump patterns and neuromuscular and biomechanical demands, in unilateral jumps a longer CT is optimal and does not necessarily indicate a slow SSC. Laffaye et al. (2016) demonstrated that the CT with the ground remains relatively constant after the age of 14 years, favouring force development for higher jumps. Furthermore, we found a negative correlation between relative PF strength and the CT in the 20+ age ($r = -.46, p < .01$) and the first-league group ($r = -.38, p < .05$). This indicates the opposite results to those reported by Beattie et al. (2017), who did not identify an association with the bilateral jump CT. In addition, previous research has indicated that the CT in jumps is associated with greater K_{vert} , as stiffer limbs can more effectively resist deformation in response to the resultant ground reaction forces in the stance phase (Brazier et al., 2019). Overall, the improvement in the RSI is primarily attributed to an increase in the JH, which consequently extends the FT. Our data suggest that for most of the U20 group, the adapted performance strategy is characterised by a longer CT, lower K_{vert} , and a higher AP and JH. However, the U17 group demonstrated the opposite performance approach, with a slightly shorter CT and a lower JH and AP. Therefore, unilateral jumps are more accurate indicators of neuromuscular adaptations of each limb that can negatively affect performance and increase the risk of injury.

Neuromuscular Readiness Analysis for Performance Optimisation

Unilateral RSI and relative PF strength benchmarking for performance identification showed that 13 participants had a poor RSI and relative PF strength; they were mostly in the U17 and first-league groups. Twelve participants had a good RSI, and 15 participants had good relative PF strength, mostly in the U20 and highest-league groups. McMahon et al. (2022) also determined T-scores thresholds (normative data) for the modified RSI, visualising it with a traffic light system. According to the T-scores performance bands, a result below the poor threshold suggests that an athlete has an insufficient level of strength for moderate to high-intensity plyometric-based activities. The U17 age group had a lower RSI compared with the U20 and 20+ age groups, indicating the strength limitations in the ankle–calf complex, as reflected in the lower AP. Athletes with low ankle strength components should incorporate maximal strength and low-level plyometric exercises into their training plan. These neuromuscular and kinetic factors, along with technical performance levels, may have a hidden association with the high ankle injury rates in floorball. A score above a good level indicates that a floorball player has well-established strength to perform plyometric-based exercises without a high risk of injury. However, the coach should frequently conduct an in-depth analysis of whether a higher strength level leads to performance improvements. Overall, 50 participants demonstrated an average unilateral RSI, while 49 showed average relative strength, highlighting the relationship between the two strength components and possible improvements in the training process. We believe that the results of the present study will encourage coaches to include ankle complex strengthening exercises and monitoring strategies in the training process, which may reduce the frequency of injuries in floorball.

One of the main potential limitations of the present study is its cross-sectional design: we collected the unilateral RSI and relative PF strength data from a sample of athletes from a single sport (i.e., floorball). Future studies should include athletes from different sports, age groups, playing levels, experience, and body composition, adjusting for equal conditions and jumping surfaces. Longitudinal monitoring is required to determine unilateral strength component development strategies, allowing coaches to integrate appropriate interventions based on the athlete's readiness benchmarks. Monitoring maximal and reactive strength following plyometrics, resistance, or combined interventions could provide insights into an athlete's physical progress. The unilateral RSI represents a valid tool for assessing readiness. This study paves the way for future floorball research, improving physical fitness, encouraging the development of technical and tactical elements, and reducing frequent lower extremity injuries by integrating appropriate monitoring strategies.

Conclusions

We investigated the unilateral foot–ankle RSI and ankle PF strength levels among floorball players to assess neuromuscular readiness for high-intensity plyometric-based activities. We found moderate to large associations between unilateral ankle PF strength and the RSI. The highest-league athletes had higher reactive and maximal strength qualities than first-league athletes, emphasising playing level differences. There were no significant differences between the playing positions, indicating the contribution of all athletes to the outcome of the game. The U20 age group demonstrated greater maximal ankle PF strength and RSI based on a higher AP and JH compared with the U17 and 20+ age groups. Overall, 13 participants had a poor RSI and poor relative PF strength, which indicates low strength for high-intensity actions. In contrast, 12 participants had a good RSI and 15 had good relative PF strength, indicating that greater strength component development is necessary to improve sport-specific performance. The findings underscore the importance of targeted ankle complex strengthening interventions for younger and lower-level floorball players to enhance jumping performance via higher power output and to reduce injury risk. Future investigations are required for longitudinal unilateral

strength monitoring in other team sports to determine the associations with performance variables according to cohort-specific benchmarks. Additionally, future research should integrate strength assessment strategies in the horizontal trajectory, examining the ability of floorball players to effectively generate horizontally orientated ground reaction force, which is crucial in the context of sprinting and change of direction performance.

Conflicts of interest

The authors declare no conflict of interest with respect to the research, authorship, and/or publication of this article.

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