

Age-related differences and normative values in motor performance of youth ice hockey goaltenders

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Abstract

Background: Motor performance evolves throughout childhood and adolescence, especially in sports that demand explosive power, rapid reaction, and flexibility. In ice hockey goaltending, these neuromuscular abilities are essential for efficient movement patterns, reflexive decision-making, and injury prevention. However, normative data specific to goaltenders remain limited evidence-based assessment and training practices. This study aimed to examine age-related differences in key motor performance tests and establish age-specific normative standards for youth ice hockey goaltenders. **Methods:** Twenty-two male goaltenders were stratified into three age groups: U9–U11 (n = 11), U13–U15 (n = 6), and U18–U20 (n = 5). All participants completed a battery of seven field-based motor tests evaluating explosive power (standing long jump, standing vertical jump), speed and coordination (upper and lower limb tapping tests), reaction time (mean of 10 trials), and flexibility (side split distance and sit-and-reach). One-way ANOVA with Tukey HSD post-hoc tests were used to compare group differences, and Pearson's correlations assessed inter-test relationships. Normative percentile bands were constructed for each age group. **Results:** Significant differences between age groups were observed in five out of the seven tests (ANOVA $p < 0.01$ for each), whereas no significant group difference was found in the side split flexibility test ($p = 0.73$). In general, the oldest goaltenders (U18–U20) demonstrated the highest performance in explosive power and speed tasks. They achieved markedly greater jump distances (long jump and vertical jump) than younger groups ($p < 0.001$) and performed more hand and foot taps in 10 s than the youngest group ($p < 0.01$). Reaction times improved (decreased) with age: both the oldest and middle groups reacted significantly faster than the youngest group ($p < 0.01$). In contrast, flexibility outcomes showed a different pattern. There were no significant differences between groups in the side split test (side split distance ~21–27 cm for all, $p = 0.735$). For the sit-and-reach test, the older goaltenders exhibited significantly greater trunk flexibility than the youngest group ($p = 0.010$). **Conclusion:** This study provides novel age-specific reference standards for motor abilities in youth goaltenders and confirms that explosive power, coordination, and reaction time improve significantly with age. Trunk flexibility, as measured by the sit-and-reach test, also increased during adolescence, in contrast to typical expectations. The findings offer a practical framework for talent identification, training individualization, and long-term athletic development in ice hockey.

Keywords: Youth athletes; goaltender development; motor performance; flexibility; reaction time; ice hockey testing; normative data.

Introduction

Ice hockey is widely recognized as the fastest team sport globally. In recent years, the development of outfield players has increasingly emphasized mastering stickhandling and skating techniques at exceptionally high speeds. Consequently, goaltenders must adapt to this evolving dynamic. As a result, growing attention has been directed toward enhancing the specific physical and performance-related attributes of goaltenders during training. The primary objective of this study is to identify effective methods for assessing these attributes and to determine the optimal age for their targeted development. To date, no widely adopted, goaltender-specific off-ice test battery has been established in the peer-reviewed literature; most standardized protocols were built around skaters and general ice-hockey fitness profiling rather than the unique demands of the crease. Seminal positional work shows that goaltenders differ in anthropometry, aerobic capacity, and flexibility from skaters, underscoring the need for dedicated assessment. Klikněte nebo klepněte sem a zadejte text.. Observational analyses of elite competition further document that goaltending is characterized by frequent vertical and lateral movements and puck-play actions, implying rapid change-of-direction, explosive force production, and high decision speed in confined spaces ((Bell et al., 2008).

Based on consultations with experienced goaltending coaches, we developed and validated a novel off-ice testing battery designed to evaluate a goaltender's preparedness for both training and competitive game demands. This test battery emphasizes four critical performance domains that are essential for maintaining high-level and consistent goaltending performance: explosive lower-limb power, reaction time, execution speed, and joint mobility. The emphasis on explosive lower-limb power is consistent with comparative on- and off-ice

findings demonstrating that higher-level players express greater jump and sprint power, Wingate peak power, and skating speed—capacities that underpin crease-to-crease recoveries and second-effort saves (Peterson et al., 2015). Joint mobility—particularly in the hip and groin—warrants specific testing because the modern “butterfly” and related techniques place the hip in extreme flexion, adduction, and internal rotation; goaltenders face both altered hip mechanics and a high burden of overuse problems across a season (Whiteside et al., 2015); (Wörner et al., 2019). Accordingly, targeted measures of passive and active hip range of motion and pain-limited function should accompany performance tests.

Although fewer in number than skater-focused protocols, emerging goaltender-specific assessments strengthen on-ice ecological validity. A case-based on-ice functional assessment after arthroscopic correction of femoroacetabular impingement used motion capture to quantify hip posture and impact loading during butterfly and braking, demonstrating meaningful side-to-side differences tied to joint morphology and mobility (Tramer et al., 2015). Equipment-centric biomechanical testing has also matured: event-specific impact protocols for goaltender masks now replicate real-world fall, puck, and collision scenarios to evaluate protective performance beyond simple drop tests, illustrating how sport-specific standards can be derived from the goaltender’s actual exposure profile (Clark et al., 2020). Complementary technique-level case work has begun to quantify goaltender-specific movement patterns (e.g., slide-to-set, butterfly recovery) and foot-ice interactions, supporting more precise links between lower-limb force, execution speed, and equipment setup (Dunne et al., 2022). Taken together, the extant literature supports a pragmatic, goaltender-centered battery that pairs general neuromuscular tests with hip-focused mobility and pain/function measures, and, where resources permit, integrates on-ice kinematics or validated surrogates of technique execution. Our proposed combination—explosive lower-limb power, reaction time, execution speed, and joint mobility—aligns with observed match demands and known injury mechanisms in goaltenders and addresses a persistent gap in standardized, position-specific testing.

Methods

Participants

A total of 22 male youth ice hockey goaltenders (ages 7–19 years) were evaluated in this cross-sectional study. Participants were drawn from development program of HC Motor České Budějovice, one of the leading clubs in the Czech Republic, with all youth teams competing in the country’s top-tier leagues. To capture critical stages of physical and motor development, participants were stratified into three official competitive age categories used in Czech ice hockey. The first group (U9–U11; ages 7–11; $n = 11$) represented early childhood through late preadolescence. The second group (U13–U15; ages 12–15; $n = 6$) corresponded to the phase typically marked by pubertal onset, growth acceleration, and neuromuscular adaptation. The third group (U18–U20; ages 16–19; $n = 5$) included goaltenders nearing or having reached biological maturity, who typically compete at a high-performance or junior-elite level. This categorization enabled the analysis of normative reference values and developmental trends in motor domains such as explosive power, tapping speed, reaction time, and flexibility.

Inclusion criteria were current registration within one of the three U-category teams at HC Motor and a minimum of two consecutive years of structured goaltender-specific training, including regular participation in team practices (at least three sessions per week during the competitive season). Participants were required to be free of acute or chronic musculoskeletal injury or illness for a minimum of four weeks prior to testing. Written informed consent was obtained from all participants (and from parents/guardians for minors) in accordance with institutional ethics standards.

Exclusion criteria included a history of orthopedic or neurological disorders that could influence motor performance, incomplete participation in the test battery, non-compliance with testing procedures, or any acute illness or injury affecting performance on the day of assessment. Players recovering from injuries within the past month that limited lower or upper limb function were also excluded.

Procedure

To assess key components of motor performance relevant to ice hockey goaltending, a battery of seven standardized field tests was administered. These tests were selected to evaluate explosive strength, neuromuscular speed, simple reaction time, and flexibility. All tests were performed under standardized conditions in a controlled indoor environment by experienced evaluators. Prior to testing, participants completed a unified warm-up consisting of five minutes of aerobic activity, dynamic stretching, and two submaximal practice trials for each motor task.

Standing Long Jump Test: Horizontal explosive power was measured via the standing long jump. Participants stood with feet shoulder-width apart behind a marked takeoff line. Using a simultaneous arm swing, they jumped maximally forward, landing bilaterally. The distance from the takeoff line to the nearest heel contact was recorded. Three trials were administered, with the longest distance analyzed (Hortobagyi et al, 1991).

Standing Vertical Jump Test: To assess lower-body explosive power, participants performed five maximal countermovement jumps beside a wall-mounted vertical scale. Standing reach height was first recorded with the dominant arm fully extended. From a standing position, participants then performed a vertical leap using arm swing and a preparatory dip. Jump height was calculated as the difference between standing reach and peak jump mark. The best attempt was used for analysis (Klavara, 2000)

Reaction Time Test: Simple reaction time was measured using a DS 35 digital reactometer (Ellab, Czech Republic). Participants sat at a table with their thumb positioned over the response button and eyes fixed on the visual cue. Following a randomized delay of 1–4 seconds, a light signal was displayed, prompting the subject to press the button as quickly as possible. Each participant completed 10 trials; the mean value of these trials (in milliseconds) was used for analysis. Reaction Training. (Silverman, 2010)

Upper Limb Tapping Test: This test assessed the neuromuscular speed and bimanual coordination of the upper limbs. Two circular targets (20 cm in diameter) of contrasting colors were positioned 81 cm apart on a horizontal surface. While seated at a table, the participant placed the dominant hand on one of the targets and the non-dominant hand centrally between them. Following an auditory start signal, the participant alternately tapped the two targets using both hands as rapidly as possible for 20 seconds. Each individual tap was scored as 0.5 points, and the total number of completed cycles was recorded. The test was performed twice, and the better performance was retained for further analysis. (Michell et al., 2008)

Lower Limb Tapping Test: Lower limb coordination and speed were evaluated using a 20-second alternating foot-tapping task. Participants stood upright and alternately tapped each foot on a 20 × 20 cm target positioned 36 cm above the floor, ensuring full-foot contact and ground return between taps. Half cycles (two taps with the same foot) were counted. Two attempts were administered; the higher score was used. The reliability of this assessment is established (Kurz et al., 2022).

Side Split Flexibility Test: Lateral hip and groin flexibility was assessed through the front split position. Participants attempted the widest possible straddle split while maintaining an upright torso against a wall. The vertical distance between the pelvis (ischial tuberosities) and the floor was measured. Lower values indicate better flexibility. The best of two trials was recorded. (Guillot et al., 2010)

Sit-and-Reach Test: To evaluate hamstring and lower back flexibility, participants sat on the floor with legs extended and feet braced against a sit-and-reach box. A horizontal measuring scale was placed such that 0 cm corresponded to the feet. Subjects reached forward as far as possible without bending the knees. Two attempts were recorded; the best distance (in cm) was used. Positive values indicated reach beyond the toes, while negative values indicated inability to reach the feet. (Mayorga-Vega et al., 2014)

Statistical Analysis

Because different participants comprised each age category (cross-sectional design), a one-way analysis of variance (ANOVA) was used to compare group means for each performance variable. Prior to conducting ANOVAs, assumptions of normality and homogeneity of variances were tested and confirmed for all measures (Shapiro–Wilk $p > 0.05$; Levene’s test $p > 0.05$). For each ANOVA that indicated a significant group effect ($\alpha = 0.05$), Tukey’s HSD post-hoc tests were performed to determine which specific age groups differed significantly from one another. In addition, Pearson correlation coefficients were computed between all pairs of test measures to examine interrelationships among the motor performance domains. A correlation matrix heatmap was generated to visualize these relationships.

Importantly, to facilitate practical interpretation of the results, we established normative reference values for each test across the three age groups. These norms were derived by calculating the 25th and 75th percentile cut-offs within each age group’s score distribution. Performance below the 25th percentile was classified as “below average,” between the 25th and 75th percentile as “average,” and above the 75th percentile as “above average” for that age group. This approach yielded age-specific normative bands for each motor test. All statistical analyses were conducted using standard software (IBM SPSS Statistics for Windows, Version 27.0, IBM Corp., Armonk, NY, USA), and significance was accepted at $p < 0.05$.

Results

Group Comparisons in Motor Performance

Overall ANOVA results indicated significant age-group differences in five out of seven tests (long jump, vertical jump, reaction time, hand tapping, and leg tapping; all $p < 0.001$; see Table 1), while no significant group effect was observed for the side split flexibility test ($p = 0.735$). The oldest goaltender group (U18–U20, 16–19 y) generally outperformed the younger groups on explosive power and speed measures, reflecting developmental gains in strength and neuromuscular coordination. Table 1 summarizes the performance outcomes by age group, including post-hoc comparisons.

In particular, standing long jump distance increased dramatically with age (mean 154.6 cm in the youngest group, 220.5 cm in U13–U15, and 257.2 cm in U18–U20), and each age group was significantly different from the others ($F_{2,19} = 45.10$, $p < 0.001$; Tukey HSD: all pairwise $p < 0.05$). A similar trend was observed in standing vertical jump height ($F_{2,19} = 20.37$, $p < 0.001$): the two older groups jumped substantially higher than the youngest group. The U18–U20 and U13–U15 goaltenders reached ~58 cm and ~47 cm in vertical jump, respectively, whereas the U9–U11 group averaged ~30 cm (post-hoc: both older groups $>$ youngest, $p < 0.01$; the ~11 cm difference between the oldest and middle groups was not statistically significant, $p = 0.11$). Upper- and lower-limb tapping speeds likewise improved with age. In the 20-second hand tapping test, the oldest group completed about 39 taps on average, compared to ~33 taps in the middle group and ~26 in the youngest ($F_{2,19} = 13.80$, $p < 0.001$; both U18–U20 and U13–U15 $>$ U9–U11, $p < 0.05$; no difference between oldest and middle, $p = 0.14$). For the leg (foot) tapping test, U18–U20 achieved ~29 taps and U13–U15 ~26 taps, versus

~18 taps in the youngest group ($F_{2,19} = 24.81$, $p < 0.001$; both older groups $>$ youngest, $p < 0.001$; oldest vs middle n.s.). Reaction time became faster (lower) with age ($F_{2,19} = 11.90$, $p < 0.001$): the U9–U11 goaltenders had the slowest reactions (~0.278 s on average), significantly slower than both the U13–U15 (0.229 s) and U18–U20 (0.204 s) groups (Tukey post-hoc, $p < 0.05$ for both comparisons). The oldest and middle groups' reaction times did not differ significantly from each other, suggesting that the most pronounced improvements in simple reaction speed occurred between the youngest and mid-adolescent stages.

Table 1. Performance in explosive power, speed, and reaction time tests by age group (mean $\pm$ SD).

Test	U9–U11 (n=11)	U13–U15 (n=6)	U18–U20 (n=5)	ANOVA p
Standing long jump (cm)	154.6 $\pm$ 20.3 ^c	220.5 $\pm$ 21.6 ^b	257.2 $\pm$ 23.4 ^a	<0.001
Standing vertical jump (cm)	29.7 $\pm$ 5.7 ^b	46.8 $\pm$ 5.7 ^a	58.0 $\pm$ 15.3 ^a	<0.001
Reaction time (ms)	278.3 $\pm$ 39.5 ^b	229.4 $\pm$ 13.6 ^a	204.4 $\pm$ 14.0 ^a	<0.001
Upper limb tapping test (taps/20 s)	25.8 $\pm$ 5.5 ^b	33.2 $\pm$ 2.7 ^a	39.0 $\pm$ 4.9 ^a	<0.001
Lower limb tapping test (taps/20 s)	18.5 $\pm$ 3.4 ^b	26.5 $\pm$ 3.4 ^a	29.4 $\pm$ 1.9 ^a	<0.001

Note: Superscript letters denote homogeneous subsets from Tukey HSD post-hoc analysis. Within a row, values that do not share a letter differ significantly ($p < 0.05$).

Flexibility Performance

Table 2 presents results for the flexibility tests, specifically the side split flexibility test and sit-and-reach tests. Flexibility measures showed a contrasting pattern to the power and speed metrics. In the wide split (side split) flexibility test, there were no statistically significant differences among the three groups ($F_{2,19} = 0.31$, $p = 0.735$). All groups achieved a similar partial split, with the distance from pelvis to floor averaging ~21–27 cm (note that a smaller distance indicates better flexibility in this test). Despite the youngest group having a slightly lower mean distance (~23 cm) than the others (~27 cm in U13–U15 and ~21 cm in U16–U20), the variability was high and these differences were not significant. In the sit-and-reach test, however, a significant age effect was found ($F_{2,19} = 5.86$, $p = 0.010$). Here, the trend opposed our initial expectations: the oldest goaltenders showed the greatest forward flexibility. The U18–U20 group reached on average 13.2 $\pm$ 6.1 cm past their toes, and the U13–U15 group 12.7 $\pm$ 7.1 cm, whereas the youngest group reached only 5.2 $\pm$ 3.8 cm beyond their toes. In practical terms, many of the 7–11 year-olds could just barely reach their toes or only slightly beyond, while the 12–19 year-olds could, on average, reach a full 12–13 cm past their feet. Post-hoc tests confirmed that the forward-bend flexibility of the youngest group was significantly lower than that of both the middle and oldest groups ($p < 0.05$); the two older groups did not differ from each other.

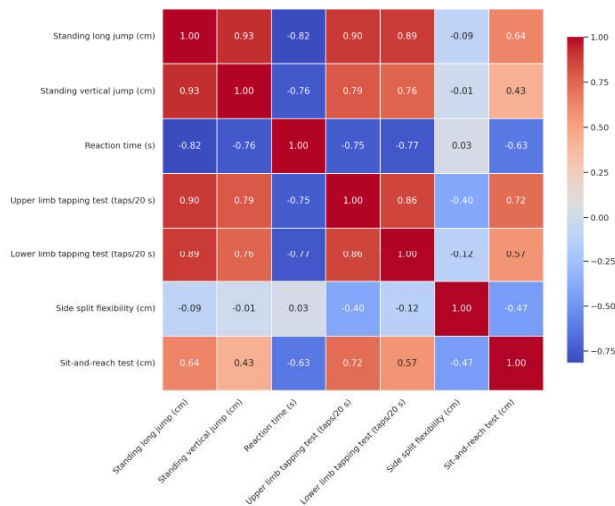
Table 2. Flexibility test results by age group (mean $\pm$ SD).

Flexibility Test	U9–U11 (n=11)	U13–U15 (n=6)	U18–U20 (n=5)	ANOVA p
Side split flexibility (cm)	23.3 $\pm$ 12.3 ^a	26.7 $\pm$ 7.1 ^a	21.2 $\pm$ 14.6 ^a	0.735
Sit-and-reach (cm)	5.2 $\pm$ 3.8 ^b	12.7 $\pm$ 7.1 ^a	13.2 $\pm$ 6.1 ^a	0.010

Note: Superscript letters indicate post-hoc group comparisons. Within a row, values that do not share a letter differ significantly ($p < 0.05$). For the side split flexibility test, a larger distance indicates a less complete split (lower flexibility), whereas for the sit-and-reach test, a larger positive value indicates farther reach beyond the toes (greater flexibility).

Correlations Between Measures

Figure 1: Correlation matrix of seven motor performance tests in youth goaltenders (Pearson's r coefficients). Warmer colors (red) denote stronger positive correlations and cooler colors (blue) indicate negative relationships. The matrix reveals two primary clusters of abilities: explosive power/speed versus flexibility. Within the power-speed domain, most variables were strongly interrelated, whereas flexibility measures showed weaker and more independent behavior.



As shown in Figure 1, the standing long jump and standing vertical jump had an exceptionally high positive correlation ($r \approx 0.93$), indicating that goaltenders who jumped farther horizontally also tended to jump higher vertically. The upper- and lower-limb tapping tests were likewise strongly correlated with each other ($r \approx 0.79$ – 0.86 in our data), reflecting a common underlying component of rapid limb movement speed or neuromuscular quickness. Both jump measures were moderately correlated with the tapping scores (for example, $r \approx 0.64$ between long jump and hand tapping), suggesting that explosive leg power and quick coordinated movements share some common determinants.

Reaction time, in contrast, showed negative correlations with the explosive power and speed metrics. Faster-reacting goaltenders (lower reaction times) tended to perform better in jumps and tapping tests. For instance, reaction time correlated around $r = -0.68$ with standing long jump and $r = -0.75$ with hand tapping, meaning those who had superior jump distances or tapping counts generally reacted more quickly to the visual stimulus. This inverse relationship aligns with expectations that more athletic, well-trained players have faster neuromuscular responses.

The flexibility tests, however, were largely uncorrelated or only weakly correlated with the other performance measures. Side split flexibility (distance from floor) was essentially independent of the power/speed traits – its correlations with jumps, taps, or reaction time were near zero ($|r| < 0.1$). This suggests that a goaltender's ability to drop into a wide lateral split is a distinct attribute, not strongly linked to how explosive or fast they are. The sit-and-reach (trunk flexibility) showed slightly stronger associations with some other tests, but still moderate at best. Notably, sit-and-reach performance had a positive correlation with hand tapping ($r \approx 0.72$) and a moderate positive correlation with long jump ($r \approx 0.5$ – 0.6).

This could imply that goaltenders who maintained better trunk flexibility also tended to do well in certain coordination or power tasks, possibly reflecting a general commitment to overall fitness or a genetic predisposition affecting multiple motor qualities. Interestingly, even the two flexibility measures were not highly correlated with each other ($r \approx -0.47$ between side split and sit-and-reach in this sample).

Some goaltenders who excelled in forward-bending flexibility were not the same individuals who excelled in lateral split flexibility, and vice versa. In summary, these correlations highlight that explosive power, speed, and quick reactions form a tightly knit group of attributes developing in tandem, whereas flexibility—particularly the lateral split ability—appears to be a more independent trait that does not necessarily parallel the development of strength or speed.

Normative Values by Age Group

To provide a practical context for coaches and athletes, normative reference values were established for each test based on the distribution of scores in each age category. Table 3 presents the performance cut-off values defining “Below Average,” “Average,” and “Above Average” performance for each test in each age group (thresholds correspond to the 25th and 75th percentiles for that group). These norms enable practitioners to gauge where a particular goaltender's result falls relative to peers in the same age range.

Across the explosive power and tapping speed tests, the normative thresholds clearly increase with age. For example, an above-average standing long jump for 7–11 year-olds is >170 cm, whereas for 16–19 year-olds it is >270 cm, reflecting the substantial gains in jumping ability with maturation. Similarly, doing more than 41 hand taps in 20 s would be considered above average in the oldest group, compared to >28 taps in the youngest group. In contrast, reaction time thresholds decrease with age (since lower times are better): an average reaction time for U9–U11 is around 300–250 ms, whereas for U18–U20 it is 230–200 ms, indicating that what is “average” reaction speed for an older teen would be elite-level fast for a younger child.

The flexibility norms show more nuanced patterns. In the sit-and-reach test, the cut-off for above-average performance actually plateaus from mid-adolescence onward: for both the U13–U15 and U18–U20 groups, reaching beyond 15 cm is considered above average, suggesting that trunk flexibility does not improve further (and may even decline or require more effort to maintain) after early adolescence.

The youngest group's above-average threshold is lower (>8 cm beyond toes), meaning that some preadolescent goaltenders already achieve reasonably good flexibility, but very high values (15+ cm beyond toes) were not observed in that group. On the other hand, in the side split test (where lower numbers indicate better flexibility), the “above average” threshold becomes smaller with age: <15 cm off the floor for the oldest group vs <21 cm for the youngest.

This implies that a truly exceptional split (getting very close to the ice) was seen only in some of the older goaltenders. It may be that years of goaltender-specific stretching and butterfly training allow a subset of older athletes to attain a superior side split, even though the group averages didn't differ significantly.

Overall, these normative values underscore the expectation of progressive improvement in explosive and reactive abilities with age, while also highlighting that flexibility traits can vary and may need targeted training to achieve or maintain high levels.

Table 3. Age group-specific normative values (based on percentile bands) for seven motor ability tests in youth ice hockey goaltenders.

	U9–U11			U13–U15			U18–U20		
	Below Avg	Avg	Above Avg	Below Avg	Avg	Above Avg	Below Avg	Avg	Above Avg
Standing long jump (cm)	<150	150–170	>170	<210	210–240	>240	<250	250–270	>270
Standing vertical jump (cm)	<27	27–33	>33	<40	40–50	>50	<50	50–68	>68
Reaction time (ms)	>300	300–250	<250	>240	240–210	<210	>230	230–200	<200
Upper limb tapping (taps/20s)	<24	24–28	>28	<31	31–35	>35	<37	37–41	>41
Lower limb tapping (taps/20s)	<17	17–21	>21	<25	25–29	>29	<28	28–30	>30
Side split flexibility (cm)	>26	26–21	<21	>30	30–23	<23	>25	25–15	<15
Sit-and-reach (cm)	<3	3–8	>8	<11	11–15	>15	<11	11–15	>15

Note: Thresholds represent approximate 25th and 75th percentile cut-offs for each group. “Below Average” denotes performance poorer than the 25th percentile for that age group, “Above Average” denotes better than the 75th percentile. Note that for reaction time, lower values are better (thus the order of thresholds is reversed), and for side split flexibility, a smaller distance from the floor indicates superior flexibility.

Discussion

This study examined age-group differences in key motor abilities of youth ice hockey goaltenders and additionally provided age-specific normative benchmarks for these abilities. The results demonstrated clear developmental improvements from childhood through late adolescence in explosive power, speed, and reaction time. The oldest adolescent goaltenders (16–19 years) significantly outperformed the younger groups in nearly all tests of power and quickness. For instance, their standing long jumps were about **65–100 cm farther** than those of 7–11 year-old goaltenders, and they performed roughly **50% more** foot taps in 20 s than the youngest players. These large differences can be attributed to the combined effects of growth, maturation, and training. During adolescence, increases in muscle mass and strength, along with neural maturation, enhance the capacity for explosive movements. Our findings align with prior research in youth sports, which shows that jumping performance and sprint-type tasks improve markedly from preadolescence to late adolescence (Retzepis et al., 2025). The observation that the performance gap between the middle (U13–U15) and oldest (U16–U20) groups is much smaller than that between the youngest (U9–U11) and middle groups—as seen in metrics like vertical jump height—suggests that the most pronounced gains occur during early adolescence, with performance progression decelerating in later teenage years as athletes approach physical maturity. Tønnessen et al. (2015) found that in adolescent #male athletes, **relative annual performance increases in jumping events peaked by age 14** and subsequently “gradually declined when approaching 18 years of age”. These findings align closely with our data, in which U13–U15 goaltenders essentially “caught up” to their older peers, indicating a plateauing effect in motor performance typically observed during late adolescence.

Reaction time also improved significantly with age in our cohort. The youngest goalies (around 9 years old on average) had reaction times about 0.05–0.07 s slower than the older groups. By mid-adolescence, 7 reaction speed was much closer to that of the oldest goaltenders, and indeed we found no statistical difference between the 12–15 y and 16–19 y groups. This indicates that substantial maturation of neural processing speed and sensorimotor integration occurs by early-to-mid adolescence, enabling quick responses to stimuli. For goaltenders, quick reaction is critical for saves, and it is encouraging to see that this ability improves with age and experience. The leveling off in reaction time gains after ~15 years might imply that basic reaction ability becomes more homogeneous among trained goaltenders once they reach a certain developmental stage. Further improvements in actual on-ice reaction performance at higher levels might then come from sport-specific anticipation and perceptual skills rather than raw simple reaction speed.

One somewhat unexpected outcome emerged in the flexibility assessments. It is widely reported that flexibility tends to decline during the adolescent growth spurt, as rapid skeletal growth can temporarily outpace the adaptability of muscle-tendon units, particularly in the posterior kinetic chain (Faigenbaum et al., 2016). Malina et al. (2004) further emphasize that while most motor qualities improve with maturation, flexibility is an exception, often showing limited enhancement or even regression during adolescence. Our initial hypothesis, therefore, posited superior flexibility among the youngest goaltenders. Contrary to expectations, however, side-split flexibility (a proxy for hip abduction mobility) showed no significant age-group differences, and sit-and-reach performance was highest in the oldest category (U16–U20), with 7–11-year-olds achieving the lowest values. Several factors may explain these findings. First, the preservation of lateral split range across age groups likely reflects the influence of consistent, position-specific training. All goaltenders in this study were regularly exposed to drills emphasizing hip mobility (e.g., butterfly movements), which may have helped mitigate

flexibility losses during growth. Second, the superior trunk and hamstring flexibility observed in older goaltenders may indicate increased engagement in off-ice stretching routines, including yoga or dedicated flexibility work, particularly among athletes preparing for higher competitive levels. Third, anthropometric differences may have played a role. Moreover, a recent systematic review by Donti et al. (2022) suggests that larger gains in joint range of motion (ROM) following high-volume stretching are more likely in children than adolescents, indicating a potential “window of opportunity” for flexibility development during preadolescence. Yet, in sports such as ice hockey—where structured mobility work is emphasized—this window may remain open longer.

Taken together, our data challenge the notion that flexibility inevitably declines through puberty. Rather, they support the view that flexibility can be preserved or even improved during adolescence, provided that targeted training is sustained. For coaches and conditioning professionals, this highlights the need to integrate structured mobility work across all developmental stages—not just during early childhood—to prevent functional deficits and support position-specific demands in sports like ice hockey.

From a coaching and talent identification perspective, our study offers practical benchmarks. We provide normative tables that coaches can use to evaluate a young goaltender’s test results against age-group standards. For example, a 10-year-old goalie who long-jumps 180 cm is performing above average for his age, whereas a 17-year-old with the same jump would be well below average among peers. These norms can help identify exceptional talents (who score “above average” across tests) as well as areas needing improvement for individual goalies (e.g., a goalie might have above-average reaction time but below-average leg speed for his age, suggesting an emphasis on quickness drills). They also allow tracking of a goaltender’s progress relative to typical developmental trajectories. However, coaches should use this information judiciously – large inter-individual differences exist, and late maturers might initially score lower on power tests but catch up as they physically mature. The ultimate goal is not to “teach to the test,” but to ensure balanced development. Younger goaltenders (pre-adolescents) should focus on mastering fundamental movement skills and can gradually introduce light plyometrics and agility exercises to build a foundation of power and coordination. As they move into early adolescence (12–15 years), training can be intensified and specialized: structured strength training, explosive drills, and reaction training can significantly boost performance in this window, which aligns with the substantial improvements we observed in that age range. For older adolescents nearing adulthood, training should be highly individualized, aiming to fine-tune strengths and address any remaining weaknesses (for instance, maintaining flexibility if heavy strength training is undertaken, or sharpening reaction and decision-making skills through on-ice scenario training). Our finding that trunk flexibility was higher in older teens than in children suggests that, with proper training, flexibility can be preserved or even enhanced, but it also raises the possibility that only those who remain flexible are able to continue excelling (a survivorship effect). Either way, it underlines the importance of integrating regular flexibility and mobility work, particularly during growth spurts when the risk of losing range of motion is highest.

Several limitations of this study should be acknowledged. First, the sample size in each age category was relatively small (especially in the oldest group, $n = 5$), which may limit the generalizability of the results. The normative values we report are preliminary and based on this single club’s cohort; a larger sample from multiple clubs would yield more robust percentile estimates. Coaches and practitioners using our normative table should do so with caution, as the “average” ranges might shift with a broader population. Second, our cross-sectional design captures differences between age groups at one point in time, but it does not track individual developmental trajectories. While we infer developmental changes, a longitudinal study following the same goaltenders as they age would provide stronger evidence of how motor abilities progress and how much individual variation exists. Relatedly, factors such as biological maturation status (e.g., early vs. late bloomers) were not controlled here – these could partly explain within-group performance variability. Third, although the test battery covered important domains of athletic performance, it was conducted in an off-ice setting and may not capture all nuances of on-ice goaltending performance (for instance, lateral slide quickness or butterfly drop speed on ice). We also used basic field tests for flexibility; more dynamic measures (like functional movement screens or specific goaltending mobility drills) were not included. The sit-and-reach and split tests have some subjectivity (e.g., discomfort tolerance) and might be influenced by limb length differences; using adjusted scoring or alternative flexibility tests could be considered in future work. Lastly, the age grouping (U9–U11, U13–U15, U18–U20) was based on the club’s system and led to slightly uneven age spans; other organizations might use different breakpoints (e.g., U10, U12, U14, etc.). Despite these limitations, this study provides a valuable snapshot of youth goaltender capabilities and a foundation for normative comparisons, but further research with larger samples and longitudinal tracking is recommended to build on these findings.

Conclusion

In summary, this analysis of youth ice hockey goaltenders across three age categories revealed that older adolescents exhibit markedly greater explosive power, faster limb movement speed, and quicker simple reaction times compared to younger players, highlighting the profound impact of maturation and training on these motor skills. Not all attributes, however, showed linear improvement with age – notably, flexibility traits displayed unique patterns. Contrary to some expectations, trunk flexibility (sit-and-reach) in our sample

increased through adolescence, with older goaltenders outperforming younger ones in forward-bending flexibility, while lateral split ability remained similar across ages. We have provided age-specific normative reference values for each test, which can serve as practical benchmarks for coaches and sport scientists. These normative standards enable the evaluation of an individual goaltender's performance relative to peers and can guide training priorities.

Overall, the findings emphasize the need for a balanced, age-appropriate conditioning approach in goaltender development. In early years, foundational strength and motor skill training should be introduced to build a platform for explosive power gains, and good flexibility habits should be established to offset potential tightening during growth. During mid-adolescence, athletes experience rapid improvements in power and speed, and training can be progressively ramped up to harness this window of adaptation – with continued attention to flexibility and injury prevention. By late adolescence, goaltenders are nearing their peak physical performance; training can focus on maximizing strength/power outputs, refining neuromuscular quickness, and maintaining mobility to ensure a well-rounded athletic profile. Coaches and trainers can use the normative data from this study to identify where a goaltender excels or lags behind typical developmental benchmarks, allowing for targeted interventions (e.g., extra flexibility sessions for those below their age norm, or advanced plyometrics for those ready to exceed their norm in power).

Future research should build on this work by examining longitudinal changes in the same athletes and by expanding the dataset across multiple clubs and competition levels. Such efforts would further validate the normative values and could investigate how training interventions at certain ages impact the developmental trajectory of a goaltender's abilities. Ultimately, a deeper understanding of age-related motor performance in goaltenders will support evidence-based training and talent development, helping young athletes reach their full potential while minimizing injury risk as they progress toward elite levels of play.

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