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Reliability and Relationship between Hip Muscle Strength and Change of Direction Performance among Basketball Players

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ABSTRACT

Background: Basketball change of direction (COD) tests are not specific to the defensive lateral shuffling movement, and no COD tests assesses the relationship between hip muscle strength and basketball specific lateral movements. **Objective:** We assessed the reliability of a COD test (2-2 shuffle test) performance and investigated its relationship to hip muscle strength. **Methods:** Using a prospective observational cohort design, data were collected from competitive male basketball players (n = 21; age 20.0 ± 3.5 years; height 194.7 ± 7.0 cm; weight 93.9 ± 14.7 kg). Participants performed two trials of the hip abductors/adductors isometric muscle strength assessment and the 2-2 shuffle test. Intraday reliability of the 2-2 shuffle test was computed using Bland-Altman plots, intraclass correlations (ICCs) with 95% confidence intervals (CI), and coefficient of variations (CVs). Pearson correlations with 95% CIs determined the relationship between shuffle test time and hip muscle's isometric strength. **Results:** The 2-2 shuffle test time for left (ICC = 0.91, CV = 7.7%) and right (ICC = 0.86, CV = 8.4%) directions met acceptable reliability thresholds (ICC > 0.8, CV < 10%). The relationships observed between 2-2 shuffle test time and hip abductors/adductors were non-significant and unclear across parameters (p = > 0.05, r = ≤ -0.26). **Conclusion:** Physical performance coaches may use the 2-2 shuffle test as the test time is a reliable metric. The hip abductors/adductors maximal isometric strength accounts for a trivial proportion of explained variance in the 2-2 shuffle test, suggesting other technical and physical abilities account for test performance.

Key words: Basketball, Muscle Strength, Physical Fitness, Fitness Testing, Physical Functional Performance, Exercise

INTRODUCTION

Basketball is a high-intensity sport and it requires players to frequently accelerate, decelerate, jump and land, quickly change direction, and do rapid shuffling movements (Abdelkrim et al., 2007; Petway et al., 2020; Scanlan et al., 2011; Stojanović et al., 2018). While basketball has a large linear movement component, lateral movements like shuffling or sliding movements can comprise up to 31% of game actions (Abdelkrim et al., 2010a; McInnes et al., 1995; Stojanović et al., 2018). Lateral shuffling is a defensive movement in basketball requiring players to shuffle sideways to face their opponents and defensively contain dribble drives. Lateral shuffling is also done to contest the ball handler from passing or shooting, challenging their ability to move sideways effectively (Morrison et al., 2022; Petway & Richman, 2022; Shimokochi et al., 2013). As such, the ability to shuffle laterally and change direction rapidly is important in basketball and to keep up with game demands.

Although the ability to accelerate and decelerate while shuffling is important, selecting tests with the best diagnostic information is more difficult than determining it is worthy of being assessed. The reason for such difficulty is that change of direction (COD) is a multifactorial and complex ability influenced by the constraints that are internal to the athlete and imparted by the task at hand (Bourgeois et al., 2017; Davids et al., 2003; Joyce & Lewindon, 2022; P Sharp et al., 2023). Further, there are an array of COD testing methods and the best approach for quantifying COD performance in basketball settings is still under debate (Morrison et al., 2022). Because of these difficulties, it is important that practitioners understand the testing characteristics to manipulate the movement solution space to mimic the competitive demands and reduce confounding factors outside the COD performance (Nimphius et al., 2018).

Historically, the agility T-test has been a key test to evaluate COD ability in basketball players (Morrison et al., 2022; Wen et al., 2018). Although the agility T-test has been shown to differentiate between players of differing playing levels (Abdelkrim et al., 2010b), it has been shown that test performance is strongly related to 5-10 m linear sprint speed (r = -0.92 to -0.83) (Poole et al., 2017). Further, the high-intensity sprinting and shuffling bout distances exceed

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those typically covered during basketball gameplay (Bourgeois et al., 2017; Leidersdorf et al., 2022; Morrison et al., 2022; Scanlan et al., 2021; Wen et al., 2018). As such, a modified version of the traditional agility T-test was developed to better replicate many team sports' high-intensity, multidirectional demands, which has been advocated for in basketball (Scanlan et al., 2021; Wen et al., 2018).

However, while the shortened distances better reflect basketball gameplay demands, it may not be the best assessment to isolate lateral COD ability because it is still difficult to know if linear speed capabilities are masking a player's ability to decelerate and accelerate laterally (Nimphius et al., 2018). Due to the limitations, a new COD test that is specific to the lateral shuffling demands is warranted. Studies investigating match-play demands in basketball (Abdelkrim et al., 2010a; Scanlan et al., 2011) have shown that players typically shuffle laterally for less than 4 m before changing movement type or direction. Notably, mean lateral shuffling distances in elite basketball players span 1.8-2.2 m (Scanlan et al., 2011), which is less than the modified agility T-test (5 m) (Wen et al., 2018). To this end, a test that is reflective of that specific characteristic and predicated on a player's ability to decelerate and reaccelerate laterally might be an appropriate test.

Thus far, only two studies (Leidersdorf et al., 2022; Shimokochi et al., 2013) have implemented an isolated lateral shuffling test in basketball players. Recently, Leidersdorf et al. (2022) investigated kinetic parameters from the lateral countermovement jump assessment that influence the capacity to perform the lateral 5-5 shuffle test among elite male basketball players. The study concluded that faster performers (2.67 s, 9.51 N/kg) in the 5-5 shuffle tended to produce more relative lateral force during a lateral countermovement jump assessment compared to their slower counterparts (2.87 s, 8.93 N/kg). Similarly, Shimokochi et al. (2013) examined kinetic and kinematic variables related to quickness in a lateral cutting manoeuvre from shuffling. These researchers found that female collegiate basketball players who displayed greater lateral ground reaction forces typically performed quicker lateral cutting manoeuvres, explaining 54% of the variance. Taken together, these results suggest the importance of lateral force produced by the player's foot pushing on the ground in the frontal plane for quicker lateral shuffling COD performance alongside an assessment of lateral COD in basketball athletes to help guide training decisions.

Maximal muscle strength assessments are a regular part of neuromuscular testing batteries for basketball players (Morrison et al., 2022; Suchomel et al., 2016). Because the hip abductors/adductors cause limb movement in the frontal plane, the strength of these muscles are considered important factors influencing the capacity to perform effective COD (McGinnis, 2020; Roozen, 2005; Shimokochi et al., 2013). For instance, two existing studies have established strong relationships (r = -0.62-0.84) between hip abductors/adductors maximal isometric strength and COD performance (90 ^{o} COD test, modified agility T-test) in basketball players (Krolikowska et al., 2023; Papla et al., 2022). However, these studies used COD tests that feature a large linear speed component. If the test is biased to linear sprint speed, this may misidentify the contribution and importance of the hip abductors/adductors muscles to lateral COD ability. Currently, no published data demonstrates any relationship between the hip abductors/adductors maximal isometric strength and lateral shuffle COD performance nor the testing reliability. An improved understanding of methods for effectively assessing lateral COD from shuffling and metrics integral to such acceleration-deceleration motions may help to inform targeted training strategies and solve performance needs.

The purpose of this research was to: (1) examine the intraday reliability of performance time for the 2-2 shuffle test in competitive male basketball players, (2) investigate the relationship between hip abductors/adductors maximal isometric strength and the 2-2 shuffle test time. We hypothesised that the 2-2 shuffle test would display acceptable reliability. It was also expected that hip abductors/adductors maximal isometric strength would be associated with quicker 2-2 shuffle time.

METHODS

Participants and Study Design

This prospective observational cohort study used an intraday design to determine the test-retest reliability. The University of Canterbury Human Ethics Committee approved the study (HREC 2023/23/LR). To be included in the study, participants must be healthy, free from any lower limb injury and must actively play competitive basketball at the national level. The sports organisation management approved the researchers to contact their players for study advertisement. The national basketball league players were informed of the study's purpose, and their consent was sought. All participants provided written consent and completed a pre-participation medical history questionnaire. Twenty-one actively competing male basketball players (age 20.0 ± 3.5 years; height 194.7 ± 7.0 cm; weight 93.9 ± 14.7 kg) were successfully recruited. Sample size calculation was not done because the tested population included the entire wider squad representing at the elite level, only the injured players were excluded.

Procedures

Before testing, each participant's age, weight, and height were recorded. Following this, the participants underwent a standardised warm-up that consisted of eight dynamic movements. During the testing session, participants completed two assessments: (1) a maximal isometric muscle strength test of the hip abductors/adductors and (2) the 2-2 shuffle test. Assessment of the hip abductors/adductors maximal isometric strength was performed using the ForceFrame (Vald Performance, Australia). This device has been previously used to measure hip strength in research, and previous studies have shown a high intraclass correlation coefficient (ICC) reliability of 0.94 (Ryan et al., 2018; Królikowska et al., 2022; Papla et al., 2022). Time for the 2-2 shuffle test was measured with a set of timing gates (SmartSpeed; Fusion Sport, Brisbane, Australia). All tests were conducted in the player's training facility on an indoor basketball court surface, and participants wore their own basketball shoes during the testing session. The participants were familiarised with the testing procedures during a pilot testing session.

Assessments

Isometric muscle strength assessment

The isometric muscle strength testing procedures was designed and adapted from O' Connor et al's (2023) strength testing procedures. Participants completed two maximal isometric contractions per joint action (abduction and adduction) where they were in a supine decubitus position under the ForceFrame with the knee and hip joint positioned in 45^o of flexion (Fig. 1). The participant's medial and lateral femoral condyles were placed between the force pads, which were adjusted according to the participant's height. For the adductor assessment, the participants squeezed their medial femoral condyle maximally against the internal force pads and sustained the contraction for 5 seconds, recorded by the tester. The abductor assessment was conducted in the same manner as the adductors, except the participants pushed their lateral femoral condyles against the external force pads. Participants were given a 3-minute recovery period between trials. Strong verbal encouragement was provided by the tester, and participants were cued to "squeeze/push as hard as possible." Peak force from the two trials was recorded for the abductor and adductor repetitions.

Change of direction assessment

The 2-2 shuffle testing procedures was designed and adapted from Leidersdorf et al (2022) and Shimokochi et al's (2013) 5-5 shuffle test. Participants performed two maximal shuffles per direction where, on their own volition, they shuffled explosively laterally from the start line to the COD line, braked with one foot crossing over the line and laterally shuffled explosively back through to the start/finish line as quickly as possible (Fig. 2). The start/finish line and the COD line were marked with 2.5 m between them. Two timing gates were placed 50 cm from the starting line (2 m from the COD line), set at 40 cm height to prevent any early triggering of the start gate. Strong verbal encouragement was provided by the tester, and participants were instructed to use their own lateral shuffle technique and "complete the task as fast as possible." This was to ensure that their lateral shuffle test technique resembled their actual game lateral shuffle movement. Participants were given a 3-minute recovery period between trials. If the participants crossed their feet during the shuffle or did not shuffle the full distance, the data was discarded, and another attempt was allowed after the recovery period. Trials one and two were included in the reliability analysis, and the quickest test time for each direction was used in the correlation analysis with isometric muscle strength data.

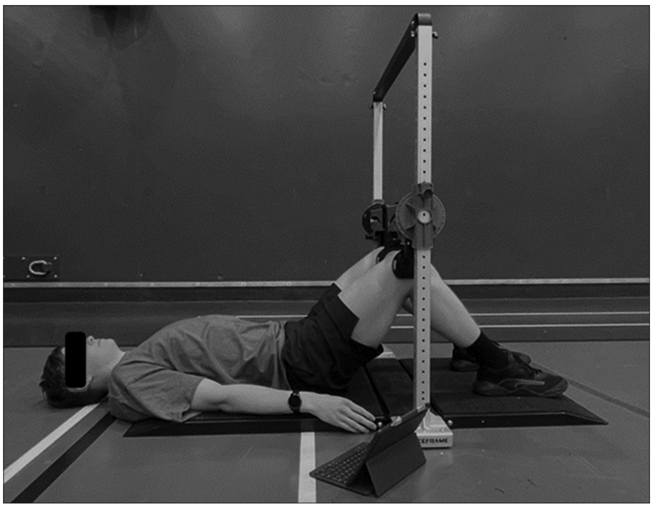

Figure 1. Isometric muscle strength testing position

Statistical Analysis

All data were analysed in IBM SPSS (version 29.0) with the alpha set at 0.05 for the threshold for statistical significance. Descriptive statistics are presented as means and standard deviations (SD) across all isometric hip strength and 2-2 shuffle measures. Intraday reliability was reported on using an ICC and coefficient of variation (CV). ICC 0.7, CV 10% and ICC 0.8, CV 5% were considered to reveal acceptable and good reliability (Weir & Vincent, 2020; Zukowski et al., 2022). Pearson correlation coefficients were used to examine relationships (r) between the 2-2 shuffle time and hip abductors/adductors maximal isometric strength. Microsoft Excel (version 16.78) was used to generate figures for the reliability and correlation analysis.

RESULTS

Descriptive statistics are presented in Table 1. 2-2 shuffle test time for both directions exhibited acceptable reliability (ICC 0.8, CV 10%) (Table 2; Fig. 3). Unclear, non-significant correlations were observed with all 2-2 shuffle test and hip abductors/adductors maximal isometric strength measures (Table 3; Fig. 4-5). The strongest correlation with 2-2 shuffle test time for the hip abductors was recorded for the right leg when the shuffle was initiated to the left (r = -0.24, p = 0.30). By contrast, for the hip adductors, the strongest correlation was observed with the right leg when the 2-2 shuffle was initiated to the left (r = -0.26, p = 0.26). The weakest relationships with 2-2 shuffle test time were observed for the hip abductors when the shuffle was initiated to the right (r = -0.06-0.11, p = 0.65-0.80) (Fig. 5).

DISCUSSION

This study analysed the intraday reliability of the 2-2 shuffle test and investigated its relationship to hip muscle strength. While an acceptable reliability in the 2-2 shuffle was observed, a weak relationship exists between hip muscle strength and 2-2 shuffle test time. Isolated lateral shuffling assessment has been conducted previously (Leidersdorf et al., 2022; Shimokochi et al., 2013), but this is the first study to investigate the intraday reliability of a lateral COD shuffling

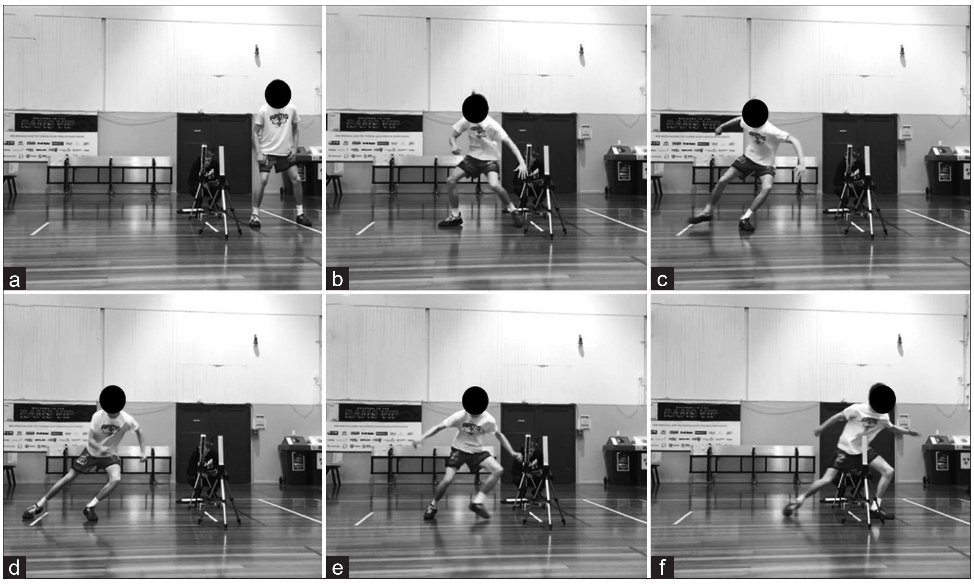

Figure 2. Experimental setup of the 2-2 shuffle test (a-f)

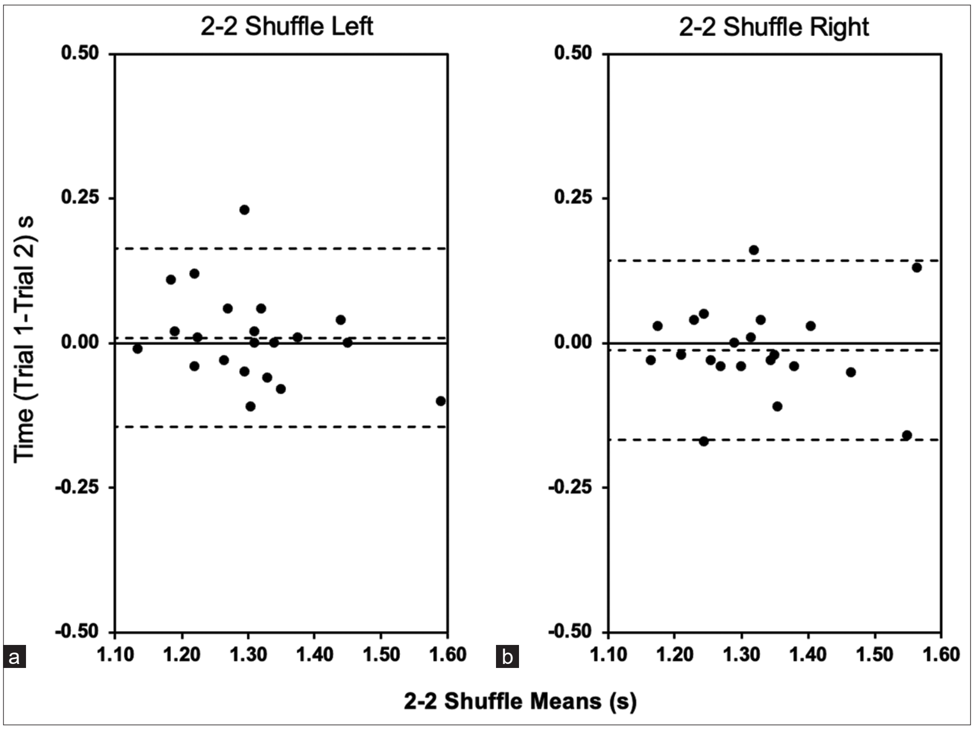

Figure 3. Mean of 2-2 shuffle vs difference in mean trials (trial 1 - trial 2).
Notes: Bland-Altman plots of the left (a) and right (b) directions, dashed lines indicate bias and 95% limits of agreement; s = seconds

Table 1. Results for all measured variables (mean±SD)

	Left	Right
2-2 Shuffle (s)	1.29 ± 0.10	1.28 ± 0.10
Hip ABD (N)	445.0 0± 90.24	438.43 ± 87.56
Hip ADD (N)	427.86 ± 90.63	439.43 ± 101.87

Notes: s = seconds; AB = abduction; ADD = adduction; N = newtons

test time in basketball players. We found that the 2-2 shuffle test time showed acceptable reliability (ICC = 0.86-0.91, CV = 7.7-8.4%) in both directions. This observation is similar to a modified T-test reliability score (Sassi et al., 2009) and a standard T-test (Pauole et al., 2000) reliability score. This suggests that our findings parallel previous studies and indicate that test time, as measured during the 2-2 shuffle, is a reliable measure in competitive male basketball players.

We also investigated the relationship between 2-2 shuffle test time and hip isometric muscle strength. Unclear non-significant relationships were established across all variables (r = -0.26, p = > 0.05). Notably, the correlation coefficients with 2-2 shuffle performance showed a stronger trend toward hip adductor maximal isometric muscle strength. Given that the participants are coached by the same staff, this pattern may be representative of the participant training history

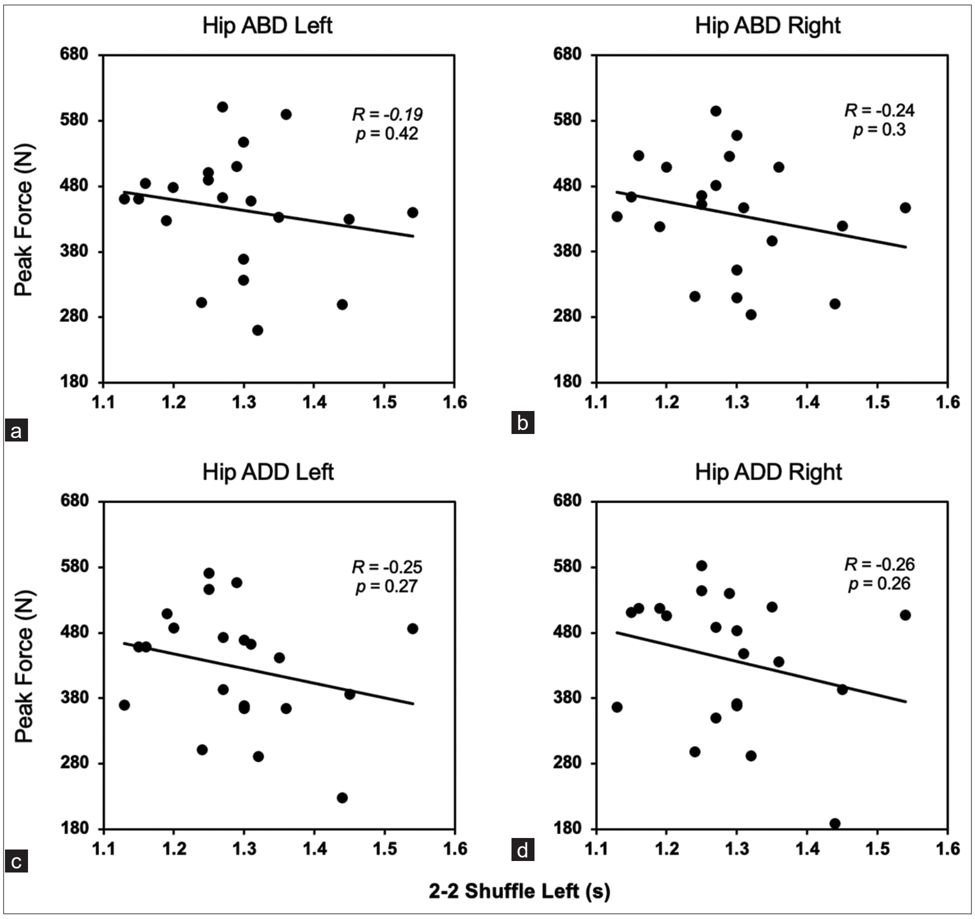

Figure 4. Relationship between the left 2-2 shuffle and isometric muscle strength
Notes: a) Hip abduction left. b) Hip abduction right. c) Hip adduction left. d) Hip adduction right. ABD = abduction; ADD = adduction; s = seconds; N = Newtons

Table 2. Intraday reliability of 2-2 shuffle parameters

2-2 Shuffle Parameter	Trial 1	Trial 2	CV	ICC (95% CI)
Left (s)	1.3 1± 0.01	1.32 ± 0.11	7.72%	0.91 (0.64-0.93)
Right (s)	1.33 ± 0.12	1.30 ± 0.12	8.43%	0.86 (0.65-0.94)

Notes: s = seconds; CV = coefficient of variation; ICC = intraclass correlation coefficient; 95% CI = 95% confidence interval

Table 3. Correlation between the 2-2 shuffle test time and isometric muscle strength

Variable	2-2 Shuffle Left (s)		2-2 Shuffle Right (s)	
	r	95% CI	*r*	95% CI
Hip ABD Left (N)	-0.19	[-0.57, 0.27]	-0.06	[-0.48, 0.38]
Hip ABD Right (N)	-0.24	[-0.61, 0.21]	-0.11	[-0.51, 0.34]
Hip ADD Left (N)	-0.25	[-0.62, 0.20]	-0.15	[-0.55, 0.30]
Hip ADD Right (N)	-0.26	[-0.62, 0.20]	-0.18	[-0.57, 0.27]

Notes: N= Newtons; s = seconds; ABD = abduction; ADD = adduction; 95% CI = 95% confidence interval; * = $p<0.05$

and techniques the players are coached to perform during defensive plays. However, despite the shift toward stronger relationships with the hip adductors, the small negative slopes, indicating a trivial decrease in 2-2 shuffle test time with increasing maximal isometric muscle strength, are insufficient to discriminate performance between participants.

Counterintuitively, stronger relationships between COD performance and hip abductors/adductors maximal isometric muscle strength have been observed using tests that feature a relatively large amount of linear sprinting with similar populations (modified agility T-test and a COD test with 90-degree turns) (Krolikowska et al., 2023; Papla et al., 2022). Such observations are paradoxical as lateral shuffling would seem to be a more specific movement pattern for frontal plane hip functions with a laterally directed push-off, which differs from linear sprinting, where force is predominantly applied horizontally in the anterior-posterior direction (Donskov et al., 2021; Petway & Richman, 2022). This may suggest that the hip abductors/adductors have more interactions to limit or enhance performance potential in tests with linear sprinting. In accordance, it has been reported that a large degree of linear sprinting performance can be explained by the hip adductor muscle cross-sectional area

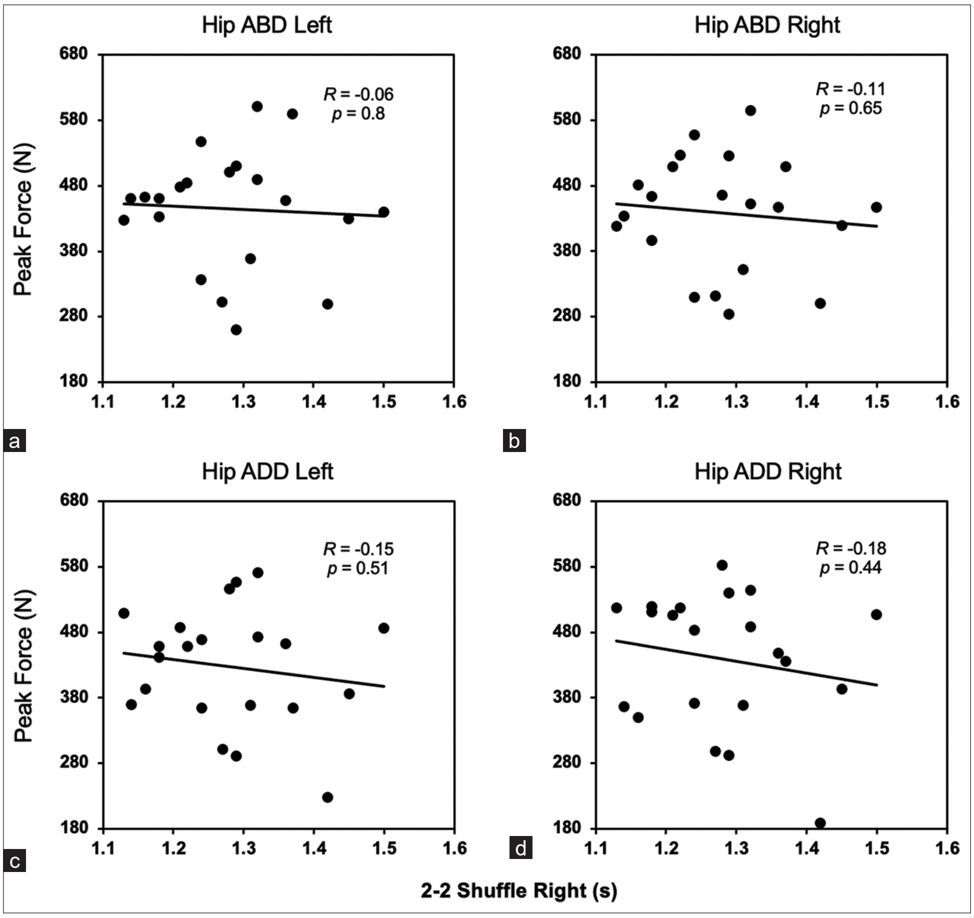

Figure –5. Relationship between the right 2-2 shuffle and isometric muscle strength
Notes: a) Hip abduction left. b) Hip abduction right. c) Hip adduction left. d) Hip adduction right. ABD = abduction; ADD = adduction; s = seconds; N = Newtons

(r = -0.65), which is directly proportional to the force producing capability (Yasuda et al., 2019). However, the differences in the turning angles, frequency of direction changes, and distance covered make it difficult to explain the shift toward stronger relationships with tests that feature linear sprinting (Bourgeois et al., 2017; Nimphius et al., 2018). It is also possible that the lack of any correlation between hip abductor/adductor strength and 2-2 shuffle performance may suggest that a strength threshold exists and that any higher strength outputs may not provide any further benefit to 2-2 shuffle performance. This notion has been discussed in a previous study, which highlighted the weak relationship between participant muscle strength and their COD performance (Hoffman et al., 2007).

However, our findings are partially supported by previous work. Shimokochi et al. (2013) observed that hip abductor motions are not highly associated with quick lateral cutting manoeuvres, instead the ability to powerfully extend the hip before making foot contact to receive high ground reaction forces was critical for faster performance (Shimokochi et al., 2013). Similarly, Kea et al. (2001) observed that hip abductor strength was not associated with jumping distance during a lateral hop test. Thus, although hip abductors/adductors maximal isometric strength was not a strong predictor of quicker 2-2 shuffle time in the current study, this study and previous work contradict the notion that improving hip abductor strength is important for performing quick lateral motions. This leads to corresponding implications on the training of lateral COD from shuffling.

This study has some limitations which should be acknowledged. Firstly, it is important to be mindful of the small sample size, which may have impacted the statistical analyses. Therefore, the data presented may only be generalisable to similar populations and restricted scenarios that involve an isolated lateral COD from a shuffling motion in anticipated situations. Secondly, participants wore their own basketball shoes, presumably with different friction coefficients between the shoe and the court surface. However, since no slipping was observed, it can be assumed that the maximal frictional forces they received were below the maximal static friction force. Thus, wearing their own basketball shoes was thought to minimally affect shuffle time. Thirdly, maximal hip strength was measured isometrically, which may appear unrelated to dynamic movements such as lateral shuffling. However, as movement velocity is given by the amount of force or impulse generated (McGinnis, 2020) the contractile force assessed isometrically provides an indication of the limb velocity that would have occurred had the limb been permitted to move.

PRACTICAL APPLICATIONS

Change of direction ability is critical for on-court performance in basketball. Assessment of the side-shuffle performance and hip muscle strength will provide specific insights about each athlete for customisation of individual training program. Implementing reactive strength exericses for improving the hip abductor/adductor reactive muscle strength may contribute to the lateral shuffle performance. The results of this study suggest that the 2-2 shuffle protocols used in this study are reliable and is basketball specific. Therefore, practitioners could include the 2-2 shuffle test as part of their fitness testing battery.

CONCLUSION

The results of this study suggest that the 2-2 shuffle protocols used in this study were reliable and showed non-significant, unclear relationships between hip abductors/adductors maximal isometric strength and 2-2 shuffle time. Basketball practitioners may consider using the 2-2 shuffle test time to measure and detect changes in lateral COD ability from a shuffling motion. Future research should investigate the predictive validity of the 2-2 shuffle test and on-court lateral performance to determine the importance of this test as reflected by tactical situations in basketball.

AUTHOR CONTRIBUTIONS

According to the definition given by the International Committee of Medical Journal Editors (ICMJE), the authors listed qualify for authorship based on making one or more of the substantial contributions to the intellectual content of:

i. Conception and design (TF, MD, SW); and/or
ii. Acquisition of data (TF, MD, SW); and/or
iii. Analysis and interpretation of data (TF); and/or
iv. Participated in drafting of the manuscript (TF, SW); and/or
v. Critical revision of the manuscript for important intellectual content (TF, MD, SW).

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ETHICAL APPROVAL INFORMATION, INSTITUTION AND NUMBER

The University of Canterbury Human Research Ethics Committee (ID: HREC 2023/23/LR) approved the experimental protocol, and all participants gave informed written consent to participate in the study.

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