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Hamstring Flexibility and Sprint Speed in Female Rugby Players after a 12-week Yoga Training

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Abstract: There is an ongoing search on how to enhance the sprint performance of athletes. One should likely start investigating beyond traditional sport-training techniques about enhancing the sprinting ability of an athlete. Female rugby players were randomly assigned to one of the two groups; an experimental group ($n = 5$) and a control group ($n = 5$). Data were collected during pre-season and end-season on hamstring flexibility and sprint performance. Unpaired t-tests with an alpha level of $p \leq 0.05$, Pearson correlation coefficient for the correlation. The experimental group significantly improved their straight leg raise test (SLR) by 29.1 ± 15.3-degrees (mean % change ± 95% CI, $p < 0.05$) and 5 m sprint time -10.4 ± 10.2 % compared to the control group 2.9 ± 15.3-degree ($p = 0.05$), and time difference of 9.9 ± 6.1% respectively. There was also a moderate negative correlation between SLR and 5 m sprint performance time ($r = -0.29$, $p < 0.05$ statistical significance. Results indicate that a 12-week yoga training helped improve the hamstring flexibility and performance of the 5 m acceleration phases of the 20 m sprint of rugby union players compared to a control group. Yoga helped rugby players to improve their hamstring flexibility when practiced alongside normal rugby training but maybe did little to improve sprint measures greater than 5 m performance during the season.

Article Type
Research Article

Keywords: *Acceleration, range of motion, physical performance, popliteal angle, straight leg raise test*

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INTRODUCTION

Rugby is one of the most popular and commonly played sports in England, Ireland, Australia, and New Zealand (World Rugby, 2017). Rugby is a highly professionalized game, and there has been a shift in the physiological and technical demands required by rugby players in the last decade; players now need to be faster and stronger to compete at a high-performance level (Darrall-Jones et al., 2015; Hill et al., 2018; Smart et al., 2013).

Sprinting is a high-intensity activity, and rugby union players spend approximately 10% of their time in higher intensity running and sprinting (Busbridge et al., 2020; Duthie et al., 2006). Rugby players spend a significant amount of time in high intensity sprinting (Busbridge et al., 2020; Cahill et al., 2013; Duthie et al., 2006). Thus, they need to have adequate flexibility of the body parts involved in the locomotor system to maintain performance and prevent injury (Ekstrand et al., 1983; Jonhagen et al., 1994; Shellock & Prentice, 1985). Indeed superior elasticity of the leg muscle-tendon unit can provide additional power to a player's running performance (Chelly & Denis, 2001). As a result, rugby players require a combination of flexibility, anaerobic endurance, and muscular contractions to produce explosive power (Lockie et al., 2015; Silder et al., 2015; Živković & Lazarević, 2011). Though flexibility is required by each individual for completing everyday activities and stretching exercises improve flexibility, it is often neglected by players.

Various studies have provided evidence of the effectiveness of stretching in increasing muscle length and joint range of motion (Raj et al., 2021; Tsolakis & Bogdanis, 2012; Vasileiou et al., 2013). Moreover, adequate flexibility may provide an ideal platform, on which skills required to develop speed and strength can be gained (Živković & Lazarević, 2011). Weerapong, Hume, and Kolt (2004) in their literature review recommended a minimum of 30 seconds and a maximum of 60 seconds should be considered in a static stretching condition to observe any changes in the muscle. Static or dynamic stretching routines are commonly used by coaches and trainers to improve flexibility (Fletcher & Jones, 2004; Gleim & McHugh, 1997), and flexibility has been a vital part of warming-up and cooling-down sessions for more than five decades (Racinais et al., 2017). Furthermore, researchers support the idea of including stretching as part of athletic training (Gleim & McHugh, 1997; Shellock & Prentice, 1985; Weerapong et al., 2004). However, the mechanisms underpinning the adaptation of the muscle-tendon unit with such training are uncertain (Akagi & Takahashi, 2014; Blazevich et al., 2014).

There is a number of possible mechanisms related to stretching, proposed by researchers, where Guissard and Duchateau (2004) observed that after 6 weeks of static stretching for 10 minutes/day, 5 days per week, there was a significant decrease in passive stiffness (torque) of the muscle along with an increased range of motion in the joint. These researchers hypothesized that the increased compliance of the muscle-tendon unit resulted from a change in the viscoelastic properties or a reduction in reflex stiffness. More explicit work by Guissard and Duchateau (2006) suggests that increased passive stiffness after stretching may be associated with either reduced motor neuron excitability. On the other hand, evidence suggests that stretch training may also reduce the tonic firing of the muscle spindle itself, probably due to a reduction in the sensitivity of the receptor or an increased compliance of the passive elastic components of the muscle-tendon unit (Guissard & Duchateau, 2004; 2006). Such stretch training may have the potential for performance gains for players (Chalmers, 2004; Sahrmann et al., 2017).

Worrell, Smith, and Winegardner (1994) also reported stretching induced muscle hypertrophy. Worrell et al. (1994) stated that 15 days of regular static stretching increases the maximal voluntary isokinetic torque, eccentric torque, and concentric torque of the hamstring muscles. Furthermore, in animals studies, Tsujimura, Kinoshita, and Abe (2006) showed that stretching the tibialis anterior muscles of young and adult rabbits at a rate of 0.5 mm 2 times a day for 20 days, resulted in muscle growth of 7.1% (adult) and 4.8% (young).

While it is commonly accepted that stretching improves the range of motion in the joint and reduces the tension in the muscle-tendon unit (Amin & Goodman, 2014; Wilson et al., 1992), whether stretching improves performance is controversial (Bazett-Jones et al., 2008). Sprinting is traditionally divided into three main phases: acceleration, maximal velocity, and deceleration (Haugen et al., 2019). Analyzing various phases of a sprint may provide greater insight for coaches and applied sport scientists into the changes in flexibility and their interaction between phases of a maximal sprint. Having an understanding of various segments during sprinting can have important implications for developing technical models of sprinting and developing technical training for future research.

A recent study reported that female players cover a similar overall distance in a game as male players (somewhere around 5 km) of which about 10% is high-intensity running and sprinting (Busbridge et al., 2020). Perhaps female players are under a similar amount of training load and increasing the ability to produce force and power of the muscle may therefore have a positive effect on athletic performances like sprinting. Even though female players are inherently more flexible than their male counterparts (Valdivia et al., 2009) Some researchers have suggested that the constant fluctuation of several female sex hormones during their menstrual cycle, may affect their exercise performance, muscle strength (Meignié et al., 2021) and perhaps flexibility. Therefore, it is also important to investigate the effects of yoga-based stretching on sprinting ability of female rugby players.

The majority of the previous studies have been conducted on male rugby players and investigated the acute effects of stretching routines on sprint performance. To date, no researchers have investigated the chronic effect of stretching (static and dynamic) routines such as yoga on flexibility and sprint performance on female rugby players.

Hatha yoga is an ancient Indian practice that involves whole-body movements to enhance joint range of motion (ROM). This type of yoga includes various static and dynamic stretching positions performed in a multi-planar manner for various durations ranging from 10-30 s. Little research has been undertaken on assessing the contribution of yoga towards enhancing flexibility and sprint performance. For this study, our objective was to determine if hatha yoga was employed as the method of chronic stretching program and practiced alongside regular rugby training to increase flexibility will there be any increase in the sprint performance analysed by phases of a sprint of female rugby players. This study also provided new frameworks that are not only addressing the issues of gender, but also highlighting the sexual inequalities in sports.

METHOD

A randomized controlled trial (convenience sample) was used to measure the effectiveness of a 12-week of yoga training on the flexibility of the lower limbs along with the sprinting ability of the players. Players were tested 1-2 days before (pre) and 1-2 days after (post) a 12-week yoga training specifically designed for rugby players.

Subjects

A total of 10 senior-level female rugby players aged 20.5 ± 1.3 (mean ± SD) volunteered to participate in the study (Table 1). None of the players had practiced yoga regularly. All female rugby union players had been playing rugby for three years or more. They were from a local rugby football club, where they attended two 90-minute rugby-specific training sessions and one game per week.

Furthermore, all the participants in the study were free from any current or previous injury that would affect their full participation in the current study. Lincoln University Human Ethics Committee approval was obtained for this study (HEC approval number 2017-14). All players were informed about the research, and they provided written consent. Four females could not complete the entire study due to their personal/family commitments, so their data were excluded from the assessment. In total, data on ten players were evaluated.

Table 1. Demographics of the participants.

	Pre-test		Post-test	
	Experimental (n=5)	Control (n=5)	Experimental (n=5)	Control (n=5)
Age (Years)	20±1	20±3	20±1	20±3
Height (cm)	166.9±4.5	172.4±5.9	166.9±4.5	172.4±5.9
Weight (kg)	70.4±7.7	72.3±6.7	71.6±8.2	75.6±6.3
Playing experience (Years)	4.4±0.8	4.2±0.74	4.4±0.8	4.2±0.74

Data are mean ± SD of each group.

Measurements

Players in this study were divided into two groups; an experimental group (EG) which practised yoga for 30 minutes two times a week in conjunction with their regular rugby training (n=5), and a control group (CG) which continued their regular rugby training but without the yoga training (n=5). During flexibility testing to reduce the influence of stretching on flexibility, participants were instructed to refrain from warming up before testing was performed. Before testing, subjects were asked to be barefoot and wear comfortable clothing, and they were asked to take a supine position in a room with the temperature controlled at 19 degrees. The tests were carried out twice with 1-minute rest given between the measurements according the procedures by Czaprowski et al. (2013). To assess the hamstring flexibility, the straight-leg-raise (SLR) test and popliteal angle (PA) test (explained below) were applied on the right and left side of the body in a randomized manner, and the results of both sides were used for analyses. The SLR and the PA tests were used to assess hamstring flexibility due to their 0.9 level of measurement reliability for each of these tests (Bland & Altman, 1997).

Straight-leg-raise test. The SLR test followed the procedure established by Czaprowski et al. (2013) which involved measuring the players in the supine position on the bed with lower limbs extended, feet relaxed, with an engaged trunk and pelvic area. The researcher randomly selected the side (right or left) to test first. As instructed, players raised either their right or left leg as high as possible until the point where discomfort was felt in the hamstring. The researcher then assessed the range of hip flexion using a goniometer (PM0064, Prestige, New Zealand) and repeated the test three times on each side of the body, while a 1-minute rest was provided between tests and the best score (joint angle in degrees) from both sides was used for analysis.

Popliteal angle test. To test the PA, the researcher followed the instructions described by Czaprowski et al. (2013). The PA was measured when the players were in the supine position on the bed with the hip flexed at 90^{O}. The player remained in this position holding the posterior aspect of the thigh. Each player was instructed to hold the thigh of the measured leg and straighten the knee until the point where discomfort was felt in the hamstring. The researcher used a goniometer (PM0064, Prestige, New Zealand) to ensure 90^{O} of hip flexion was maintained during measurement of the opposite side hamstring. The player was asked to straighten the lower leg, and another researcher used the goniometer (PM0064, Prestige, New Zealand) to measure the popliteal angle. The test was repeated three times on each side of the body, with one-min rest provided between tests and the best score (joint angle in degrees) from both sides was used for analysis.

Sprinting. Twenty metre sprint performance was analysed in this study using a protocol described by Darrall-Jones et al. (2015). Since sprinting is divided into acceleration, constant velocity and deceleration phases (Haugen et al., 2019), the 20 m sprint was analysed over the first five and 10 m (acceleration), and maximal velocity was measured over the final 10 m. Analysing the sprint phases could help the author to determine the exact phase of a sprint that may improve or have the maximum effect on flexibility and sprinting phase. Each player was required to complete two, 20m sprints from a standing start position with two minutes of recovery time between each sprint. The player placed her lead foot behind the 30 cm mark starting line and ran through the electronic timing gates placed at 5, 10, and 20 m (i.e. Fusion Sport, Coopers Plains, Australia).

Yoga Training

A 30-minute yoga training class was given twice a week for 12 weeks (24 sessions total) by a registered yoga instructor (Table 2). All players attended at least 75% (18) of the yoga sessions, consisting of different postures designed to address all the major muscle groups, including the hamstring, quadriceps, and abductors. Each player actively performed 21 yoga postures in total which involved all possible planes of the body, 11 of which were static stretching postures and 10 were dynamic stretching postures. A sun salutation (dynamic stretching sequence of 12 postures) was used for warm-up and savasana was used as a final resting position (no stretching included).

To ensure the uniformity of the yoga sessions, the yoga teacher performed the postures in front of the players prior to the players trying the posture on their own, each posture was held for approximately 10 to 30 seconds, as controlled by the researcher. A minimum of five seconds were also allocated for changing the postures, also a minimum of 30 s rest was given between the transition of the postures from a standing position, to a sitting position, to a supine, and to a prone position. Seven of the 21 postures were focused on stretching the lower body (e.g. adho-mukha svanasana, and prasarita paddottansana), these were performed as both static and dynamic and either in a standing or in a supine position. Three of the 21 postures were stretching the shoulder region (e.g. bandha hastasana) of the body which was also performed either in a standing or sitting position. Five of the 21 postures were variations of the sit-and-reach posture for stretching the anterior and posterior planes of the body.

Table 2. Yoga postures used in the training.

	Name of the Posture	Time*	R##	Total
	Sun-salutation#	300		300
1.	Samsthiti	30	X1	30
2.	Bandha Hastasan	10	X2	20
3.	Gomukha asana	10	X2	20
4.	Uttanasan	15	X1	15
5.	AdhoMukha Svanasan	30	X2	60
6.	Uttanasan	20		20
7.	Virbhadrasan II	20	X2	40
8.	Parasvakonasan	15	X2	30
9.	Virbhdrasan I	15	X2	30
10.	Prasarita Paddottansan	20		20
11.	Parsva Uttanasan	15	X2	30
12.	Uttanasana	30	X2	30
13.	Janu Sirsasan	15	X2	30
14.	Paschimouttanasan	15	X2	30
15.	Marichyasan	20	X2	40
16.	Supta Padangustasan I	30	X2	60
17.	Bhujangasan	10	X2	20
18.	Urdhva Mukha Svanasan	10	X2	20
19.	Shahshank asana	10	X2	20
20.	Setu bandhasan	10	X2	20
21.	Jathra parivartanasan	10	X2	20
	Savasan**	300		300
				1205

#: used as a warm-up, *: Time in seconds, ##R: number of repetitions, Total: time spent in stretching condition, **: used for the final relaxation.

Four of the 21 postures focussed on supine postures (e.g. supta padangustasana 1 and setu-bandh asana). Two of the 21 postures were to twist and provide length in the spinal region. The yoga training was progressively challenging, and all players were in the same yoga class which was completed in a large open fitness studio room. Players were verbally encouraged to perform the yoga posture to the best of their ability. The yoga training protocol with the postures involved is listed in Table 2.

Data Analysis

The 10 players were able to complete the study. The Statistical Analysis System (Version 9.3, SAS Institute, Cary NC) was used to calculate means and standard deviations for the various anatomical and performance measures from each of the two tests (pre versus post). Residuals from the SAS output were initially checked for normality (popliteal angle, straight leg raise test, sprint time 5, 10, 15, and 20 m). Differences in variables between the yoga and control groups were determined using unpaired t-tests with an alpha level of $p \leq 0.05$ (Table 3). Pearson correlations were computed between selected variables to provide an indication of the overall association between the testing protocols. P-values were also reported.

Findings

Players spent the first four minutes performing sun-salutation sequence (e.g. a set of 12 dynamic stretching postures used as warm-up) an easy to follow practice to keep the practice standard throughout the study. Players then performed 8 sets of 15 s stretches focussing on quadriceps, hamstring, calves in six different postures, 5 sets of 20 s stretches focusing on gluteal and lower back area in six postures, 9 sets of 10 s stretching focussing on shoulders, upper-back, and abdominal in five postures, two sets of 10 s stretching focussing on middle back in one posture, and two sets of 20 s stretching focussing on hip abductor and hip adductors in two postures. Typically, a combination of joints and muscle are used during each posture. Total time spent on stretches amounted to 21 ± 2 minutes (mean ± SD) at each yoga session. Players spent approximately 13 minutes performing dynamic stretching, which included 4 minutes of sun-salutation practice, and around 8-9 minutes in both dynamic and static stretching postures. Players were also required to do a 5 minutes of savasana/mindful relaxation/recovery at the end of the session. Only five female players in the yoga group were able to complete the study, two of the five players attended all 24 sessions, one player missed six sessions (none of them were consecutive sessions) due to personal circumstances. Two players missed two consecutive sessions due to injury.

Table 3. Pearson correlation of female rugby players after a 12-week yoga training.

	SLR Right Leg	**SLR Left Leg**	**PA Right Leg**	**PA Left Leg**	**5 m ST**	**10 m ST**	**15 m ST**	**20 m ST**
SLR Right leg	1.00	0.72	0.67	0.55	0.06	0.06	0.09	0.21
		0.00	0.00	0.01	0.79	0.81	0.70	0.38
	20	20	20	20	20	20	20	20
SLR Left Leg	0.72	1.00	0.50	0.44	-0.29	-0.09	-0.17	0.23
	0.00		0.02	0.05	0.25	0.70	0.48	0.32
	20	20	20	20	20	20	20	20
PA Right Leg	0.67	0.50	1.00	0.54	-0.17	-0.26	-0.27	-0.07
	0.00	0.02		0.01	0.47	0.27	0.24	0.77
	20	20	20	20	20	20	20	20
PA Left Leg	0.55	0.44	0.54	1.00	-0.04	0.047	-0.03	0.26
	0.01	0.05	0.01		0.85	0.85	0.89	0.27
	20	20	20	20	20	20	20	20
5 m ST	0.06	-0.29	-0.17	-0.04	1.00	0.83	0.81	0.28
	0.79	0.23	0.47	0.85		<.0001	<.0001	0.24
	20	20	20	20	20	20	20	20
10 m ST	0.06	-0.09	-0.26	0.047	0.83	1.00	0.77	0.37
	0.81	0.70	0.27	0.85	<.0001		<.0001	0.11
	20	20	20	20	20	20	20	20
15 m ST	0.09	-0.17	-0.27	-0.03	0.81	0.77	1.00	0.67
	0.70	0.48	0.24	0.89	<.0001	<.0001		0.00
	20	20	20	20	20	20	20	20
20 m ST	0.21	0.23	-0.07	0.26	0.28	0.37	0.67	1.00
	0.38	0.32	0.77	0.27	0.24	0.11	0.00	
	20	20	20	20	20	20	20	20

*Correlation is significant at the 0.05 level (2-tailed).

Table 4. Change in the flexibility and sprint time in female rugby players before and after a 12-week yoga training.

	Control Group			Experimental Group			
	Pre (n = 5)	Post (n = 5)	Pre-Post-Change (± 95% CL)	Pre (n = 5)	Post (n = 5)	Pre-Post-Change (± 95% CL)	Between Group Pre-Post % Change (± 95% CL)
SLR Right Leg (0)	75.6±7.7	81.80 ± 7.2	8.0% (13.7	66.6±11.7	85.8±10.3	26.1% (9.6)	19.8 % (21.3)
SLR Left Leg (0)	78.4±10.4	80.4 ± 8.5	2.9% (18.6)	64.8±11.9	86.0 ± 4.3	29.1% (15.3) *	30.0 % (33.4)
PA Right Leg (0)	44.0±5.1	42.0 ± 4.5	-6.5% (35.0)	39.6±16.7	55.8 ± 3.4	42.1% (57.6)	62.5 % (131.1)
PA Left Leg (0)	43.0±15.5	49.8 ± 3.1	18.6% (30.1)	35.4±14.4	53.0± 2.8	47.3% (52.9)	33.2 % (95.6)
5 m ST (s)	1.06±0.08	1.31±0.03	9.9% (6.1)	1.28±0.15	1.11±0.10	-10.4% (10.2) *	-18.4 % (10.6)
10 m ST (s)	2.03±0.08	2.14 ± 0.09	5.1% (4.6)	2.09±0.15	1.90±0.10	-3.5% (2.3)	-8.3 % (5.4)
15 m ST (s)	2.83±0.71	2.90 ± 0.07	3.4% (5.3)	2.89±0.13	2.76±0.03	-5.8% (4.1)	-8.8 % (6.5)
20 m ST (s)	3.62±0.03	3.70±0.28	1.3% (6.7)	3.49±0.22	3.3±0.24	-1.3% (1.6)	-2.6 % (8.3)

Data are mean ± SD of each group with the difference between groups given as the mean ± 95% confidence interval. D: Angle measured in degree; s: time measured in seconds; SLR, Straight Leg Raise Test, PA, Popliteal Angle Test; * Statically significantly ($p < 0.05$).

There were no statistically significant differences in any of the measures between the groups at baseline (Table 4). There was no significant change in the PA as a result of the yoga training, but the players who completed the 12-week yoga training significantly improved their SLR test 29.1 ± 15.3-degrees (mean % change ± 95% CI, $p < 0.05$) (Table 4). The control group did not change significantly 2.9 ± 15.3 ($p = 0.05$). Also players who completed the 12-week yoga training significantly improved their 5 m sprint (acceleration phase) time -10.4 ± 10.2 compared to the control group 9.9 ± 6.1 (mean % change ± 95% CI, $p < 0.05$). There was also a moderate negative correlation between the straight leg raise and the 5 m sprint performance time ($r = -0.29$).

The findings in this study indicate that after a 12-week yoga based stretching routine the biggest improvement in hamstring flexibility was achieved in SLR test by the female rugby players performing yoga combination of static and dynamic exercises. Only in the SLR test and 5 m sprint distance a significant improvement was achieved. However, it is difficult to decide why one of the two tests (SLR and PA) and only 5 m acceleration phase of 20 m sprint resulted significantly higher compared to the control group. The PA, 10, 15, and 20 m results of the yoga group were higher compared to the control group, however it did not reach statistical significance compared to the control group.

DISCUSSION

The present study was designed to assess the effects of a yoga (stretching) training on the sprint speed and lower extremity flexibility of female rugby players when practised alongside regular in-season rugby training. The primary findings of the study were a significantly faster sprint time in 5 m acceleration phase of 20 m sprint and improved SLR hamstring flexibility of both legs (but only reaching statistical significance in the left leg) in the experimental group. We also observed a small negative correlation ($r = -0.29$) between the SLR and sprint time among the experimental group as well as an improved hamstring flexibility being associated with improved 5 m sprint time by a mean of -18.4 ± 10.6 (mean % change ± 95% CI, $p < 0.05$).

While researchers have investigated the effectiveness of stretching routines mostly on males, including rugby players (Caplan et al., 2009; Fletcher & Jones, 2004), sprinters (Jonhagen et al., 1994), soccer players (Sayers et al., 2008), and young adults (Bradley et al., 2007), this is the first study to examine a yoga (stretching) programme for female rugby players. After measuring the players and comparing with the norms available the author (s) found out that players flexibility was below these norms (Gray & Naylor, 2009). Yoga is known to increase the joint range of motion

(Amin & Goodman, 2014) and decrease recovery time (Brunelle et al., 2015), therefore we hypothesised that including yoga alongside regular training might improve the flexibility and sprint performance of the players in this study.

There is a considerable amount of literature indicating that static and dynamic stretching (as used in this study during the yoga session) are effective at improving flexibility in both acute and chronic settings (Caplan et al., 2009; Kokkonen et al., 2007; LaRoche & Connolly, 2006; Worrell et al., 1994). However, to our knowledge, there is a paucity of information on the effectiveness of a yoga training or a mixed-method (static and dynamic) stretching routine on improving sprint performance and flexibility. It is speculated that flexibility is increased when the muscle-tendon unit decreases its stiffness (Wilson et al., 1992). This is supported by previous work from LaRoche and Connolly (2006) who reported that flexibility is increased from enhanced stretching tolerance of the muscle, implying an adaptation and change in the elastic properties of skeletal muscle in response to the stretching programme. Researchers have also suggested a temporal effect prior to flexibility change, which can take between 3-8 weeks (LaRoche & Connolly, 2006; Turki-Belkhiria et al., 2014) or 8-12 weeks (Raj et al., 2017) depending on the intensity of stretching. Since neither stretch tolerance nor muscle -tendon unit stiffness was measured directly in the current study, the mechanism underlying the gains in the flexibility of the players in this study are undetermined.

Previous research indicates that the benefits from a regular stretching programme are improved flexibility, and increased strength (Kokkonen et al., 2007). Although flexibility gains are correlated with reduced sprint time, this correlation may not show a direct cause and effect. Kokkonen et al. (2007) reported that recreationally active male and female participants in a stretching group increased flexibility and decreased sprint time which were related to the change in the muscular strength. Likewise, yoga postures included in the training in this study may have increased muscle length which may have led to increased contractile velocity and force generation. An increase in muscle hypertrophy in the leg muscles of the players in the yoga group in this study may have increased the strength and therefore power of these players resulting in the improved 5 m sprint time, however this is speculative until we can substantiate this theory with muscle strength and power data in subsequent studies. Future research could include such measures to help understand the mechanisms involved.

Another unique aspect of the training that may have played a role in the sprint improvement observed in the experimental group could be the inclusion dynamic stretching. Previous work suggests that dynamic stretching leads to enhanced motor unit excitability and improved kinaesthetic sense leading to improved proprioception and pre-activation (Mann & Jones, 1999). Furthermore, dynamic stretching may help in re-using the elastic energy during exercise that involves a stretch-shortening cycle (e.g. sprinting) (Wilson et al., 1992). However, this study only found a significant improvement in the 5 m explosive sprint in our experimental group and suggest more research on a larger population would be required to establish whether yoga or dynamic stretching does actually improve sprinting performance in this way.

The first limitation in this study was in regards to the number of groups and the types of stretches assigned to each group. The nature of this study involved using a mix of stretching routines to improve rugby player performance. Perhaps using separate stretching groups (one group doing dynamic only stretching and another doing static only stretching) could have provided more information. The second limitation was that we did not have a 3rd group to observe a potential placebo effect. The third limitation was that we had a small sample size and as a result, we were unable to run more rigorous statistics (if we had more groups, we could have run multivariate analysis). Fourth limitation was that the power and strength of the groups were not measured before and after the training, which could have been important factors for performance measurement. Fifth limitation was while using female players in the study, we could have kept a record of their menstrual cycle to establish whether this influenced the study outcomes. Finally, we could have measured other affected body parts such as quadriceps and gastrocnemius etc. Therefore, future studies are needed to include larger sample sizes, more groups (perhaps including sprinters versus distance running athletes), specific muscle groups, strength, and power tests, recording of menstrual cycles, and more specific statistical analysis.

CONCLUSION

In conclusion, a 12-week stretching programme (yoga programme in this study that involved both static and dynamic stretching) significantly improved the explosive 5 m sprint (e.g. time over the first 5 m) in female rugby players compared to controls. The stretching programme also improved flexibility of the hamstring muscles in the leg. It seems that a yoga programme that involves 30 minutes twice a week for 12 weeks can positively affect hamstring flexibility as well as 5 m sprinting performance in female team sport players. Our results suggest that a well-planned and controlled yoga programme incorporating static and dynamic stretches is worthwhile for improving hamstring flexibility and explosive speed in young female rugby players. However, these results should be considered speculative because of the many study limitations and would require further research before yoga can consistently show a positive effect on players' sprint performance.

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