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Aquatic Exercise Compared to Contrast Therapy With Shallow Water Treadmill Running to Assist Recovery in Elite Australian Rules Footballers

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The purpose of this pilot exploratory study was to determine any immediate effects of a session of aquatic exercise (AE) compared with contrast therapy shallow water treadmill running (CSWR). Twenty-nine elite footballers were allocated randomly to AE or CSWR, 48 hr after a practice match. Outcome measures included maximum vertical jump height; visual analog scale (VAS) for pain; the squeeze test for adductor strength, sit and reach test, and ankle and hip range of movement. A significant difference between groups was found for maximum vertical jump height with the AE group being able to jump higher after the intervention (95% CI [-8.63 to -1.28]). No other significant differences between groups were detected for any outcome. Significant within group effects were found for the CSWR group in improving sit and reach (p = .04), and reducing pain when performing the squeeze test (p = .02). Both interventions may have improved aspects of performance; however, more highly powered trials, incorporating a control group, need to be conducted.

Keywords: aquatic exercise, aquatic therapy, contrast therapy shallow water treadmill running

Back and lower limb musculoskeletal strains are the most common injuries leading to missed games in Australian football league (AFL) players (Orchard & Seward, 2010). Even more players cannot train or play optimally due to the effects of minor joint overload or delayed onset muscle soreness (DOMS). Aquatic exercise (AE) and contrast therapy shallow water treadmill running (CSWR; cyclical immersion in cold and warm water with shallow water running) are used to assist musculoskeletal recovery and improve function, pain, strength, and flexibility in elite AFL players.

Exercise in water has advantages for recovery. For example, water buoyancy can reduce weight bearing load (Edlich et al., 1987; Harrison & Bulstrode, 1987); hydrostatic pressure can reduce joint and muscle swelling (Edlich et al., 1987); and

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the temperature of the water, both warm and cold, can reduce pain (Enwemeka et al., 2002; Michlovitz, 1996). Recovery has been defined as a complex multisystem (e.g., psychological, physiological, social, environmental, behavioral) process for the reestablishment of performance abilities over time (Kellmann, 2002).

Although AE has been shown to reduce pain and improve function, joint mobility, and strength in older adults and in people with rheumatic conditions (Geytenbeek, 2002), few studies have investigated the effects of AE on minor musculoskeletal injury rehabilitation or recovery in athletes. One study (Kim, Kim, Kang, Lee & Childers, 2010) examined the effects of AE compared with land exercise in national level athletes with lower limb injuries. A greater reduction in pain was reported by those completing the aquatic program. Another study (Takahashi, Ishihara, & Aoki, 2006) of long distance runners showed that 3 aquatic exercise sessions held over 3 consecutive days reduced calf muscle stiffness and decreased muscle soreness. Together, these studies suggest that AE could assist recovery after participation in sports. The sample sizes were small, study outcomes were heterogenous, and the interventions often lacked sufficient detail about program supervision, how the exercises were performed, and the depth of immersion.

Despite being used in clinical practice, there is currently no evidence available about the effects of contrast therapy combined with shallow water treadmill running. Results from studies investigating the effects of contrast therapy alone (i.e., cyclic immersion in cold and warm water) have shown reductions in pain and functional deficits in strength-trained males (Vaile, Gill, & Blazevich, 2007; Vaile, Halson, Gill, & Dawson, 2008). A recent systematic review (Hing, White, Bouaaphone, & Lee, 2008) concluded that overall outcomes in studies of passive contrast therapy in athletes were inconclusive and the use of active exercise in combination with contrast therapy was recommended.

A number of studies have investigated the effects of shallow water treadmill running alone, in a range of populations such as young, recreationally competitive runners (Silvers, Rutledge, & Dolny, 2007), college athletes (Brubaker, Ozemek, Gonzalez, Wiley, & Collins, 2011), and older, less physically fit adults (Greene, Greene, Carbuhn, Green, & Crouse, 2011). These studies have focused predominantly on cardiorespiratory outcomes such as the effects on heart rate and V_{O2max} (Brubaker et al., 2011; Gleim & Nicholas, 1989; Greene et al., 2011; Napoletan & Hicks, 1995; Pohl & Mcnaughton, 2003; Rutledge, Silvers, Browder, & Dolny, 2007; Silvers et al., 2007). The findings from these studies suggest that shallow water treadmill running can elicit similar cardiorespiratory responses to land treadmill running. Consideration should be given to depth of immersion (Gleim & Nicholas, 1989; Napoletan & Hicks, 1995; Pohl & Mcnaughton, 2003) and the use of water jets for additional resistance (Greene et al., 2011; Silvers et al., 2007). No previous studies have investigated the effects of shallow water treadmill running on musculoskeletal recovery in elite athletes.

Given these considerations, the primary aim of this pilot exploratory randomized clinical trial was to examine the immediate effects of a single session of AE compared with a single session of CSWR on physical function, pain, adductor strength, and range of movement (ROM). The secondary aims were to (1) determine any within-group systematic effects for AE and for CSWR on physical function, pain, adductor strength, and lower limb range of movement (ROM) in football players 48 hr after a match, and (2) provide estimates of effect size within-group and between-group for each outcome measure. These effect sizes could then be used to help guide appropriate sample sizes for use in future, more highly powered studies.

Method

Participants

Participants were recruited from an AFL Club 2 days after an intraclub practice match. Volunteers were included if they completed at least 50% of the match. This was to ensure that players had participated in enough exercise to potentially elicit symptoms of DOMS or joint overload. Participants with minor (grade 1) ankle ligament injuries and lower limb hematomas were included, because these injuries are common in AFL players, thus the effects of the interventions on these participants were of interest.

Volunteers were excluded if they had any contraindications to immersion in a hydrotherapy pool (Larsen et al., 2002) such as gastroenteritis, risk of infection (e.g., open wounds), injuries that required attendance at a medical appointment as a priority, or the team doctor determined there was risk of further injury (e.g., unstable joint, significant pain). One of the investigators (SH) held an informational session to explain the study and answer any questions one week before the trial. Approval was granted by the university ethics committee and written informed consent was obtained from each participant before testing.

A total of 29 men from the Club's list of 48 footballers were recruited. Seventeen players were excluded as they did not play in the practice match due to injury or illness or being on an interstate training camp. One player was excluded by the team doctor due to a knee injury sustained during the game and one was excluded as he had played less than 50% of game time. Fourteen men were allocated to the AE group and 15 men were allocated to the CSWR group.

Procedures

Participants were randomly allocated to the CSWR group or the AE group. Randomization was achieved using a computer-based, random sequence generator (Haahr, n.d). Allocation was concealed in consecutive, sealed, opaque envelopes. Allocation remained concealed until baseline assessment was completed, at which point an investigator (not the outcome assessor) handed the participant the next envelope in the sequence. All participants had some experience of both of the interventions as part of usual practice in the months before the testing.

Interventions

Aquatic exercise. Participants allocated to the AE group completed a program of exercises supervised by an experienced aquatic physiotherapist. Exercises took place in the Football Club's pool which was 1.3–2 m deep. Due to varying heights of participants and the fixed depth of the pool, the percentage of body mass supported by the lower limbs could not be standardized. At the shallow end, most participants were immersed to the level of the xiphoid process allowing a reduction in weight bearing of approximately 35% of bodyweight (Harrison & Bulstrode, 1987). Water temperature was kept at thermoneutral (35°C), meaning that core body temperature was unaffected (Hall, Bisson & O'Hare, 1990).

The AE program took 45 min and involved 2.5 min at each of 18 exercise stations. An experienced aquatic physiotherapist designed the AE program, and the exercises comprised functional closed-chain exercises, balance exercises, and dynamic or passive stretching. All of the exercises either (a) mimicked movements used in running or Australian football game skills (e.g., kicking), (b) consisted of movements typically restricted in Australian footballers (e.g., hip and spinal rotation, hamstring length), or (c) covered a range of joint movements of the spine and lower limb in all planes. Table 1 summarizes the exercises. Participants exercised with no more than 8 others to enable the physiotherapist to adequately monitor the participants' technique. All participants began at station 1 in the shallow end of the pool and moved around the circuit in the same order.

Contrast therapy shallow water treadmill running. Participants allocated to the CSWR group completed a 16-min program supervised by the Football Club's Fitness Advisor. CSWR took place in the football club's plunge pools at a depth

Table 1 Aquatic Exercises

Station	Exercise	Depth (Approximately)
1	Mimic kicking action while walking across pool	1.3 m
2	Passive gluteal stretch in sitting (on pool steps)	0.7 m
3	Passive buoyancy assisted hamstring stretch with 2 noodle floats	1.3 m
4	Passive buoyancy assisted quadriceps stretch with 2 noodle floats	1.3 m
5	Passive buoyancy assisted trunk lateral flexion stretch with 2 noodle floats	1.3 m
6	Passive calf stretch	1.3 m
7	Dynamic lunge walk across pool with trunk rotation	1.3 m
8	Side lunges across pool	1.3 m
9	Walk along noodle	1.3 m
10	Single leg squat with hip rotation	1.3 m
11	Walk feet up wall into spinal flexion, then extend knees	2 m
12	Spinal rotation on wall of pool	2 m
13	Hip internal and external rotation on wall of pool	2 m
14	Push off wall in prone then roll to supine and land in sitting position	1.5 m
15	Supine to prone roll with simultaneous shoulder elevation and spinal extension	2 m
16	Vertical float—Hip flexion and external rotation	2 m
17	Vertical float to horizontal float with alternating trunk lateral flexion	2 m
18	Bound and hold landing position	1.3 m

of 1.3 m, which was approximately level with the xiphoid process of the sternum of most players. This caused some unloading of lower limb joints but also enough weight bearing to allow a running pattern similar to on land. Shallow water running at this depth has been shown to decrease peak vertical forces to 0.39–1.24 body weight (mean 0.80, *SD* ± 0.24 body weight), from the 1.60–4.0 body weight that occurs in land running (Haupenthal, Ruschel, Hubert, de Brito Fontana, & Roesler, 2010). The treadmill speed was set at 6.0 kph, allowing for a symmetrical jog but not requiring movements to extremes of joint range or muscle length.

Participants commenced with 2 min running on a treadmill immersed in warm water (40.3°C) and then moved immediately to another treadmill immersed in cool water (11°C) for 2 min. This cycle was repeated 4 times. The selected conditions were consistent with current recommendations for contrast therapy, specifically, a 1:1 warm-cold ratio with warm temperatures between 38–40° and cold temperatures of 10–15°C (Halson, 2011). The duration of contrast therapy also was similar to the recommended 14–15 min (Halson, 2011).

Outcome Measures

Outcome measures were taken immediately before and after participants completed their allocated intervention in the football club's rehabilitation gymnasium. The same outcome assessors who were blind to group allocation performed all assessments. Randomization occurred after the first outcome measures were taken. Blinding was maintained in the second set of outcome assessment by instructing participants not to inform the outcome assessor about which group they were in.

Baseline demographic data comprising the participant's age, height, and weight were collected from the Football Club's web site. These details are recorded by the exercise science staff at each club and are an accurate reflection of the participant's demographic data. If any player had sustained an injury, a diagnosis was sought from the Football Club's doctor. Other information such as medications taken (e.g., nonsteroidal anti-inflammatory drugs) or history of any injury was obtained by the club physiotherapist who spoke to participants individually. These data were collected to help determine whether the two groups were similar at baseline, allowing clearer interpretation of observed changes.

Lower limb function. Vertical jump height can be substantially reduced following intense exercise (Gorostiaga et al., 2010), and, ultimately, can decrease player performance. The Optojump video analysis system (Glatthorn et al., 2011) was therefore used to measure maximum height reached during a counter movement jump (CMJ). The OptoJump system (Microgate; Bolzano, Italy) is a video analysis system that allows temporospatial measures of jumping to be recorded and analyzed. It consists of a transmitter and receiving bar with LEDs that communicate continuously. The system detects any interruption in communication between the two bars and calculates their duration. The Optojump bars are linked to a computer where dedicated software can then quantify jump height. This system has very high concurrent validity with a force plate system (ICC 0.997–0.998) and excellent retest reliability over 1 week (ICC 0.982–0.989) for estimating vertical jump height (Glatthorn et al., 2011).

Players wore underwear and a nonpermanent ink mark was made on the anterior superior iliac spine (ASIS), greater trochanter, tibial tuberosity, and lateral malleolus. Participants stood on a mark on the floor in front of the video system. They were given standardized instructions to perform one maximum effort CMJ. Participants began in an upright position with their hands on their hips. They were instructed to flex their knees (approximately 90°) as quickly as possible and then jump as high as possible.

Severity of pain. A standard 10 cm horizontal visual analog scale (VAS), with anchors referenced as "no pain" and "extreme pain" was used to measure severity of lower limb pain at rest and during hopping. Pain at rest was only analyzed descriptively. The VAS has been shown to have high retest reliability with an ICC of 0.97 (95% CI = 0.96–0.98; Bijur, Silver, & Gallagher, 2001).

Adductor squeeze test. The adductor squeeze test is a pain provocation test that is often used for injury screening and prevention in athletes (Delahunt, Kennelly, McEntee, Coughlan & Green, 2011). It is a useful diagnostic tool (Verrall, Slavotinek, Barnes, & Fon, 2005) that consists of 2 measures, specifically, adductor strength and self-reported pain with an isometric contraction. Players lay in crook lying with 60° hip flexion, and a sphygmomanometer was placed between their knees. The player was instructed to squeeze his knees together as hard as possible. Adductor force (mmHg) and self-reported pain (out of 10 using a VAS) was then recorded. The squeeze test has been reported to have acceptable retest reliability over 30 min (ICC > 0.75) and football players with groin pain were found to have significantly reduced force production ($p > .05$; Malliaras, Hogan, Nawrocki, Crossley & Schache, 2009). Consequently, the squeeze test can discriminate between football players with and without groin pain (Malliaras et al., 2009). It also has been suggested that hip adductor muscle strength is reduced preceding and during the onset of groin injury in young elite footballers (Crow et al., 2011) therefore the squeeze test may have a role in the early detection of groin injury.

Lower limb joint range of movement. Reduced hip ROM has been found to be associated with chronic groin injury ($p = .03$; Verrall et al., 2007), therefore passive hip internal (IR) and external rotation (ER) range was measured. This was assessed at 90° hip flexion in supine using a goniometer. Retest reliability using a goniometer has been found to be high over 1 week, with an ICC of 0.95 for measurement of passive IR and an ICC of 0.91 for passive ER (Nussbaumer et al., 2010).

The dorsiflexion lunge (measuring angle) was used to measure ankle dorsiflexion in standing. This has excellent retest reliability over 1 week, with an ICC of 0.98 (95% CI 0.93–0.99; Bennell et al., 1998). The sit and reach test was used as a measure of lumbar spine and hamstring muscle flexibility in long sitting. The sit and reach test has high retest reliability over 1 week, with an ICC of 0.99 (95% CI 0.98–1.00; Gabbe, Bennell, Wajswelner, & Finch, 2004).

Data Analysis

The within-group (pre- and posttest) analyses were performed with paired *t* tests. The effect sizes were computed with the difference in pre- and posttest outcome means divided by the pretest standard deviation (Lipsey & Wilson, 2001). To calculate effect sizes for tests involving both limbs, a consolidated computation of results from both limbs was performed with the between measurement covariances considered.

Given that this is a pilot study where the objective is to present preliminary evidence about the problems under investigation, no Bonferroni adjustments are recommended as there could be a substantial reduction in the statistical power of rejecting an incorrect null hypothesis in each test (Perneger, 1998). Type I errors cannot decrease without inflating type II errors. In fact, one of the aims of the pilot study is to permit preliminary testing of the hypotheses that leads to testing more precise hypotheses in the full-scale study. It may lead to changing some hypotheses, dropping some, or developing new hypotheses.

The between-group analyses were carried out with the generalized linear modeling (GLM; Hardin & Hilbe, 2012) framework. The specific choice of the model depended on the nature of the posttest outcomes and the data structure. The outcomes of vertical jump height, severity of pain when hopping, adductor squeeze test and its associated self-reported pain with VAS and sit and reach test were analyzed with an underlying Gaussian distribution and an identity link so that the reported regression coefficients of Group (1: AE, 2: CSWR) could be interpreted as the between-group difference in average posttest outcome. The pretest outcomes were included in the models as covariates so that the results for between-group differences were adjusted for baseline imbalances. On the other hand, linear mixed models with Gaussian distribution and identity link (Hardin & Hilbe, 2012) were applied to analyze the posttest outcomes of hip internal (IR ROM), external rotation (ER ROM), and dorsiflexion lunge, as the individual players' readings were obtained from both limbs. In these cases, the individual observations for both limbs were nested within the individual players, thus exhibiting a multilevel data structure. The conventional regression models fail to provide efficient estimates of the between-group difference. Conceptually, it is also inappropriate to analyze the results from both limbs separately.

No power and sample size calculations were performed. A pilot or exploratory study is a small scale, preliminary study conducted before the full-scale study is launched. A major reason for conducting a pilot study is to provide the information required to calculate sample size for a larger fully powered study. The recommendations for sample size calculations for pilot studies are merely rules of thumb (Browne, 1995).

Analyzed with Stata 12.0 (Stata Corp, Texas, USA), all statistical tests were conducted with 95% confidence intervals (equivalent to 5% level of significance).

Results

Table 2 summarizes the demographic characteristics of both groups. As the table shows, there were no between-group baseline demographic differences detected. There were the same number of injuries in both groups; however, 4 players in the CSWR group reported general soreness compared with 2 in the AE group. On the day of the trial, only one person required anti-inflammatory medication and he was in the CSWR group.

In the CSWR group, one participant who sustained a minor knee meniscal injury was unable to jog symmetrically on the treadmills due to pain. This person only participated in contrast immersion, not the treadmill running. Similarly, one participant in the AE group had moderate pain with the spinal flexion exercise (walking feet up wall) so he did not complete this exercise. Data from these subjects were analyzed on an 'intention-to-treat' basis, which meant that data were analyzed as allocated and no estimated values were inputted for any missing data.

Outcome Measures

Table 3 summarizes the pretest and posttest outcomes together with the results of the within-group statistical analysis. Table 4 summarizes the within group effect sizes. Table 5 summarizes the between group GLM analyses.

Table 2 Sample Characteristics at Baseline

		Aquatic Exercise (AE)	**Contrast Therapy Shallow Water Treadmill Running (CSWR)**
		***n* = 14**	***n* = 15**
Age (years)	Mean (s.d.)	22.4 (3.1)	22.3 (3.7)
Height (cm)		186.2 (5.1)	187.8 (4.8)
Weight (kg)		85.5 (6.7)	86.3 (7.1)
NSAIDs-day of study	No. (%)	0 (0.0)	1 (6.7)
Incidence of lower limb injury (sprain, hematoma, pain)		3 (21.4)	3 (20.0)
		Gluteals: 2	Hip: 2
		Knee: 1	Groin: 1
Postgame lower limb discomfort (new symptoms)		7 (50.0)	7 (46.7)
		Gluteals: 3	Gluteals: 1
		Groin:1	Hip: 2
		Knee: 1	Groin: 1
		Ankle: 2	Ankle: 2
			Shin: 1
Ongoing lower limb injury or discomfort		3 (21.4)	3 (20.0)
		Gluteals: 1	Hip: 1
		Ankle: 1	Groin: 1
		Calf: 1	Shin: 1
Lower back discomfort or ongoing injury		4 (28.6)	5 (33.3)
General soreness		**2 (14.3)**	**4 (26.7)**

Table 3 Outcome Measures, Mean (SD) of Groups, and Within-Group Effects

	Aquatic Exercise			Contrast Therapy Shallow Water Treadmill Running		
	Pretest	Posttest		Pretest	Posttest	
Outcomes	**Mean *(SD)***	**Mean *(SD)***	**p-value**	**Mean *(SD)***	**Mean *(SD)***	**p-value**
Lower limb function, counter movement, jump (cm)	43.15 (7.17)	46.57 (5.04)	0.08	42.50 (6.34)	41.25 (6.34)	0.22
Self-reported severity of pain VAS (hopping)	0.57 (1.22)	0.64 (1.34)	0.84	1.20 (1.70)	0.36 (0.93)	0.15
Adductor squeeze test (mmHg)	238.57 (23.24)	246.79 (30.80)	0.12	215.33 (35.07)	224.00 (32.25)	0.06
VAS squeeze test	1.79 (0.89)	1.57 (1.09)	0.43	2.2 (1.32)	1.53 (0.92)	0.02*
Lower limb range movement			0.86			0.91
Hip internal (degrees)						
Right	44.86 (13.52)	45.36 (12.04)		46.87 (6.91)	45.93 (7.42)	
Left	38.21 (8.80)	41.29 (8.23)		35.53 (10.62)	38.07 (9.47)	
External rotation (degrees)			0.68			0.81
Right	55.71 (10.60)	58.50 (12.63)		57.73 (11.54)	62.73 (7.97)	
Left	55.79 (7.40)	59.71 (11.55)		63.40 (8.18)	62.47 (7.85)	
Dorsiflexion lunge (degrees)			0.86			0.99
Right	42.36 (3.77)	42.43 (4.59)		45.67 (6.10)	45.53 (5.53)	
Left	42.93 (4.41)	41.57 (4.55)		44.07 (7.77)	44.20 (6.16)	
Sit and reach test	-4.68 (10.74)	-3.43 (9.91)	0.10	-1.93 (11.20)	-0.20 (9.53)	0.04*

*Significant at $p < 0.05$ level.

Table 4 Within-Group Effect Sizes

	Aquatic Exercise	Contrast Therapy Shallow Water Treadmill Running
	Within-Group Pre- & Posteffect Size	Within-Group Pre- & Posteffect Size
Lower limb function		
Counter movement jump (cm)	0.48	0.20
Self-reported severity of pain		
VAS (hopping)	0.06	-0.49
Adductor squeeze test	0.35	0.25
VAS squeeze test	-0.25	-0.51
Lower limb range movement		
Hip internal (degrees)	0.18	0.12
External rotation (degrees)	0.43	0.25
Dorsiflexion lunge (degrees)	-0.18	0.00
Sit and reach test	0.12	0.15

Physical function. According to GLM, there was a significant difference in maximum vertical jump height during CMJ between the two groups (95% CI [-8.63 to -1.28]), with a lower mean value reported for the subjects assigned to CSWR. While the AE group exhibited an improvement in CMJ, the CSWR group experienced a small decline in average posttest CMJ. Specifically, the CSWR reported a lower mean posttest maximum vertical jump height during CMJ by 4.95cm when compared with the AE group after adjusting for the pretest CMJ (Table 5a). As Table 3 shows, neither group showed significant within-group changes for maximum vertical jump height during CMJ.

Pain. While the CSWR group showed a substantial improvement in posttest evaluation in terms of pain when hopping (VAS), the difference of 0.39 units when compared with the AE group was not statistically significant (95% CI [-1.28–0.50] after adjusting for pretest VAS (Table 5b). Similarly, no significant within-group changes were found for either group. At baseline, the highest VAS score recorded at rest was 4/10 with a total of 4 players reporting pain (AE $n = 2$, CSWR $n = 2$). At baseline, the highest VAS score when hopping was 5/10 with a total of 9 players reporting pain (AE $n = 3$, CSWR $n = 6$). However, 7 of the 8 players in the CSWR group who reported pain, either at rest or during hopping at baseline had no pain after the intervention. In the AE group, 1 of the 5 players who had reported pain, either at rest or during hopping had no pain after intervention.

Adductor squeeze test. No significant between-group improvements were seen for pain or adductor strength on the squeeze test. However, the CSWR group did report lower average values for both sets of posttest measurements when compared with the AE group, after adjusting for the pretest measurements (Table 5c).

As Table 3 shows, a systematic within-group improvement in the CSWR group was detected for pain (p = 0.02; d = -0.51) and values approached significance for adductor strength (p = .06; d = 0.25).

Lower limb joint range of movement. No group improved more than the other for any of the ROM measures according to the mixed models (Table 5d). The CSWR group reported higher average values for dorsiflexion lunge and sit and reach test when compared with the AE group, but the difference was not statistically significant (Table 5e).

A significant within-group improvement was found in the CSWR group for the sit and reach test (p = .04; d = 0.15). No significant within-group changes were found for internal or external rotation of the hip or for the dorsiflexion lunge (Table 3).

Table 5 Between-Group Analysis of Posttest Outcomes

(a) Lower Limb Function

	CMJ (cm)	
	Coefficient	**95% C.I.**
Group		
AE	Reference	Reference
CSWR	-4.95 *	-8.63– -1.28
Pretest outcome	0.56 *	0.24–0.89

*Statistically significant at 5%.

(b) Self-Reported Severity of Pain

	During Hopping	
	Coefficient	**95% C.I.**
Group		
AE	Reference	Reference
CSWR	-0.39	-1.28–0.50
Pretest outcome	0.14	-0.16–0.45

(c) Adductor Squeeze Test

	Adductor Force (mmHG)		VAS Squeeze Test	
	Coefficient	**95% C.I.**	**Coefficient**	**95% C.I.**
Group				
AE	Reference	Reference	Reference	Reference
CSWR	-2.16	-15.18–10.85	-0.21	-0.81-0.30
Pretest outcome	0.89 *	0.73–1.05	0.53 *	0.28–0.77

*Statistically significant at 5%.

(continued)

Table 5 *(continued)*

(d) Lower Limb Joint Range Movement

	Hip Internal (IR ROM)		External Rotation (ER ROM)	
	Coefficient	95% C.I.	Coefficient	95% C.I.
Group				
AE	Reference	Reference	Reference	Reference
CSWR	-1.11	-4.62–2.40	0.15	-4.01–4.32
Pretest outcome	0.63 *	0.45–0.81	0.69 *	0.49–0.90

*Statistically significant at 5%.

(e) Dorsiflexion Lunge and Sit and Reach Test

	Dorsiflexion lunge		Sit and reach test (cm)	
	Coefficient	95% C.I.	Coefficient	95% C.I.
Group				
AE	Reference	Reference	Reference	Reference
CSWR	1.20	-0.44–2.84	0.87	-0.87–2.61
Pretest outcome	0.75 *	0.62–0.88	0.86	0.77–0.94

*Statistically significant at 5%.

Adverse events. Adverse effects were minimal. After CSWR, one player who at baseline had no pain at rest, reported anterior knee pain at rest (VAS 2/10), and another player who at baseline had no pain at rest or when hopping reported right foot pain at rest and when hopping (VAS 3/10). After completing the AE intervention, one player who initially didn't have pain reported left ankle pain when hopping (VAS 4/10). In no case was the pain severe enough for the players to discontinue the intervention and all players were able to participate in the subsequent training session.

Discussion

The results of this exploratory pilot study suggest that one session of AE may be more effective than one session of CSWR in improving vertical jump height during CMJ in AFL footballers. Examination of the within-group systematic changes suggest that immediately after completing CSWR, participants tended to have less pain when performing the squeeze test and greater flexibility in the sit and reach test. These findings suggest that both interventions may have improved certain aspects of the athlete's performance. This may help guide clinicians to select the most appropriate aquatic recovery intervention for an individual's particular presenting problem, related to pain or functional deficits.

Participants in the AE group showed a significantly greater maximum vertical jump height during CMJ immediately after the intervention, which is a key change in physical function. A mean change of 3.42 cm was found between pre- and postmeasures, but individual improvement was as much as 20 cm. The AE intervention included a variety of dynamic movements including propulsive push off from wall, bounding and landing, lunging, and single leg squats. Although the focus of the program was not power-based and exercises were not performed to maximal effort, it did mimic the key components of jumping, using part practice in a supportive environment as a form of motor skill learning. There is some evidence to suggest that part practice can lead to greater performance (Mane, Adams, & Donchin, 1989; Newell, Carlton, Fisher, & Rutter, 1989; Park, Wilde, & Shea, 2004). Low load exercise targeting the gluteal muscles has also shown improvements in vertical jump height in a similar group of elite athletes (Crow, Buttifant, Kearny & Hrysomallis, 2012). This indicates there may be some transfer of increased muscle activation from low load exercise to explosive power movements. Functional, partially weight bearing, low load aquatic exercise may have similar mechanisms and benefits leading to improvements in functional peak power output.

Although statistically no changes were found for pain when hopping, descriptively it appeared that CSWR may be beneficial for decreasing pain when hopping and pain at rest. After the CSWR intervention, all of the players who initially reported pain at rest and 5 of the 6 who reported pain when hopping, had no pain. Only 1 of the players in the AE group who reported pain at rest or when hopping had no pain following the intervention. It is possible that the small number of players reporting pain resulted in these changes not being detected statistically.

Although the numbers of players who reported pain was low in this study, this is very different from during the season when pain and minor injury can be a substantial issue (Orchard & Seward, 2010). The incidence and severity of symptoms in these players did not accurately reflect the incidence during the season as the study took place after a preseason intraclub practice match. This meant that players in the study were less likely to be carrying an injury and had played only 48 min of game time, compared with the 80 min of playing time (excluding stoppages) in a normal AFL match (Australian Football League, 2011).

As this is the first study to investigate CSWR, a direct comparison with findings from previous literature is not possible. A reduction in pain is consistent with two previous studies investigating passive contrast therapy alone. A significant improvement ($p < .01$) in DOMs-related perceived pain 24, 48, 72 hrs post-exercise was found in 38 strength-trained males (Vaile, Halson, Gill, & Dawson, 2008) and a reduction in mean perceived soreness was found in 13 recreational athletes after contrast therapy (Vaile, Gill, & Blazevich, 2007). The physiological mechanisms resulting in changes in pain and DOMs with contrast therapy relate to hydrostatic pressure and the temperature of the water. The exact contribution of each of these characteristics of water to recovery and the ideal combination of depth and temperature is unknown. In addition the contribution of the exercise type and timing of immersion need to be considered (Halson, 2011). Hydrostatic pressure relates to depth of immersion and causes an inward and upward displacement of body fluid reducing edema, increasing extracellular fluid transfer into the vascular system, and increasing cardiac output which may assist the metabolism of waste products from exercise and assist muscle repair (Wilcock, Cronin, & Hing, 2006). Contrast therapy relates to alternating temperature which may cause a similar action to vasopumping or mechanical squeezing to help remove metabolites (Wilcock et al., 2006).

Pain on the squeeze test significantly decreased within the CSWR group (p = .02) and values approached significance for adductor strength (p = .06). It is likely that this decrease in pain reduced muscle inhibition, which allowed greater muscle activation and consequently an increase in force production during the squeeze test. This is an encouraging finding as groin pain is common in AFL where there are high levels of side to side, twisting, and kicking movements (Fricker, Taunton, & Ammann, 1991). Groin pain is consistently among the top three causes for missed playing time in the AFL and has a high rate of recurrence and a risk of becoming chronic (Orchard & Seward, 2010).

A reduction in pain could have also contributed to the significant improvement in the sit and reach test in the CSWR group (p = .04). Over half the participants in the current study reported lower back or gluteal pain or discomfort at baseline. This could potentially have led to poorer sit and reach results because this test assesses lumbar spine and hamstring muscle flexibility (Rolls & George, 2004). This finding contrasts with a previous study of passive contrast therapy alone, which found no significant improvements in sit and reach immediately after a single AFL match (Dawson, Gow, Modra, Bishop, & Stewart, 2005). Active immersion including walking, jogging, and jumping in warm water also did not significantly affect sit and reach (Takahashi, Ishihara, & Aoki, 2006). One study on recovery following a basketball game found that the sit and reach test was best maintained by immediate passive cold water immersion (Montgomery et al., 2008). It appears that it may be the combination of movement and contrast immersion that increased sit and reach performance in this study. This may be desirable in players with significantly reduced muscle length which impacts on function. Unlike sit and reach, which is a measure of active ROM, the passive ROM outcomes, for the most part, did not change with either intervention. The most likely explanation for this is that the player's passive range was not restricted at baseline.

CSWR and AE appear to be safe under supervision in this population with few adverse effects reported. Only two participants from the CSWR group and one participant in the AE group reported mild pain after the interventions. In particular, there were no detrimental effects on back, hip, or groin symptoms with both interventions showing a mean improvement for pain and strength in the squeeze test which is important in this population (Malliaras et al., 2009). With reduced load in water comes reduced stability with movement. Therefore, prescription of aquatic exercise must consider the base of support, depth, starting position, and speed of movement to ensure appropriate lumbo-pelvic control and no adverse effects following the intervention in a recovery or rehabilitation session. The dynamic exercises included in the AE program appear to have been stable enough to allow controlled low load activation that led to some improvements in jumping. Given the nonsignificant changes in ROM, less static stretching and more low load controlled dynamic movement should be considered in aquatic exercise programs in the future.

Limitations

This study provides the first investigation comparing the effects of two different types of aquatic interventions used in the recovery of elite AFL football players. In addition, estimates of effect sizes have been provided and can be used in future, more highly powered randomized controlled trials (RCTs). There were some limitations, including no measurement of a control group which received no intervention or passive immersion in thermoneutral water. It is therefore difficult to quantify the effect of exercise versus hydrostatic pressure or water temperature. The different length of immersion between the two groups may have also influenced the results as the AE group was immersed for more than twice as long as the CSWR group. These times reflected clinical practice within this team at this point in time. Comparing AE and CSWR interventions of a similar time should be considered in the future. In addition, the order of testing of the outcome measures was not randomized and this may have influenced the results. The order was chosen so participants alternated between a more strenuous outcome measure (e.g., CMJ or strength assessment) and a less strenuous outcome measure (e.g., ROM assessment) to avoid effects of fatigue. A further limitation may be the small number of participants who reported pain. This may not be a true representation of the frequency or intensity of pain after a game during the season, and so future research in this area may consider collecting data in-season. Future research also might consider measuring multiple bouts of AE or CSWR exercise in a full training week rather than just the effects of a single bout of immersion.

Conclusions

A statistically significant between-group difference was found for participants in the AE group to be able to jump higher than participants in the CSWR group. This finding suggests that the AE program may be more effective if the purpose of the intervention is to improve sports specific functional activity. Alternatively, within-group findings suggest that CSWR might be effective in increasing flexibility and reducing groin pain. Descriptive analysis also may suggest further potential benefits in reducing pain with CSWR. In clinical practice, the findings of this pilot study may help clinicians make more informed decisions about the most effective aquatic recovery intervention for a particular athlete depending on their symptoms and function. For athletes with more issues with pain or flexibility after intense exercise, CSWR may be more beneficial, and for athletes with reduced power or more functional limitations AE may be the aquatic intervention with more value. Using the effect sizes reported in this study, more highly powered RCTs, incorporating a control group, need to be conducted to further evaluate these interventions.

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