Title: Recovery from repeated on-court tennis sessions; combining cold water immersion, compression and sleep recovery interventions.

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ABSTRACT:

Purpose: The current study investigated the effects of combining cold water immersion (CWI), full-body compression garments (CG) and sleep hygiene recommendations on physical, physiological and perceptual recovery following two a day, on-court training and match-play sessions.

Methods: In a cross-over design, 8 highly-trained tennis players completed two sessions of on-court tennis drill training and match-play, followed by a recovery or control condition. Recovery interventions included a mixture of 15min CWI, 3h of wearing full-body CG and following sleep hygiene recommendations that night; whilst the control condition involved post-session stretching and no regulation of sleeping patterns. Technical performance (stroke and error rates), physical performance (accelerometery, counter-movement jump), physiological (heart rate, blood lactate) and perceptual (mood, exertion and soreness) measures were recorded from each on-court session, along with sleep quantity each night.

Results: While stroke and error rates did not differ in the drill session ($P>0.05;d<0.20$), large effects were evident for increased time in play and stroke rate in match-play following the recovery interventions ($P>0.05;d>0.90$). Although accelerometry values did not differ between conditions ($P>0.05;d<0.20$), CMJ tended to be improved before match-play with recovery ($P>0.05;d=0.90$). Further, CWI and CG resulted in faster post-session reductions in heart rate and lactate and reduced perceived soreness ($P>0.05;d>1.00$). Further, sleep hygiene recommendations increased sleep quantity ($P>0.05;d>2.00$) and also maintained lower perceived soreness and fatigue ($P<0.05;d>2.00$).

Conclusions: Mixed-method recovery interventions (CWI and CG) used after tennis sessions increased ensuing time in play, lower-body power and reduced perceived soreness. Further, sleep hygiene recommendations assisted the reduction of perceived soreness.

INTRODUCTION

On-court tennis training[1] and match-play[2] involve prolonged, physically demanding activity profiles, resulting in substantial elevation of physiological and perceptual strain and reduced contractile function.[3,4] Moreover, professional tennis involves year-round scheduling of tournaments, requiring a continued balance of competition to gain/defend ranking points; whilst also ensuring sufficient training for technical and physical capacity improvement.[5] To ensure appropriate portioning of time to these demands, players are accustomed to performing multiple sessions a day: generally with a technical, match-play or physical focus.[5] Accordingly, the need for recovery for ensuing training or competition demands is of importance for professional players. The use of interventions such as cold water immersion (CWI) and compression garments (CG) to assist recovery are popular and supported through research in other sports[6,7,8]; whilst the role of sleep to assist athlete recovery also remains an integral but rarely researched area.[9] In a similar vein, the effect of combining these recovery techniques into a mixed-method protocol, and application of such a protocol to repeated tennis sessions has not been reported.

The use of CWI and CG's are common recovery tools, often owing to their availability at many competitions (CWI) and portability (CG) during regular travel.[7,10,11] CWI, by virtue of temperature or hydrostatic pressure, is reported to be beneficial to post-exercise recovery, particularly if muscle damage or physiological perturbations are extensive.[12,13] Despite some conjecture,[14] CWI induced temperature or pressure-mediated effects can reduce thermoregulatory and cardiovascular load, muscle damage markers and improve singular and repeated maximal efforts;[15,16] which may be of relevance to the frequent training required in competitive tennis.[5] CG in turn are suggested to promote reduced metabolic waste products, increase venous return and reduce inflammation[7,17,18]. However, evidence for improved recovery of physiological or performance variables following the use of full- or lower-body compression therapy is limited;[7,17,18] though improved recovery of lower-body power and perceived soreness have been reported in other sports.[7,19,20]

Despite the popular use of the aforementioned interventions, a common issue for recovery from training or competition relates to sub-optimal sleeping patterns noted in athletic populations.[9,21] Sleep is reported to be integral to the metabolic, cognitive and physiological regenerative processes fundamental to recovery.[9] Indeed, the absence of sleep is reported to blunt muscle glycogen synthesis, elevate thermoregulatory and cardiovascular demands and slow cognitive and physical performance.[22,23] Sleep extension protocols inclusive of sleep hygiene recommendations improve sleep quantity over time and are reported to improve sports performance[24], yet no studies report whether a such sleep hygiene recommendations can improve ensuing post-exercise recovery in athletes. Further, currently there is no research on the effects of mixed-method recovery interventions, as are anecdotally reported to be used in tennis. Accordingly, the application of mixed-method recovery interventions (CWI, CG and sleep hygiene recommendations) may be of relevance to professional tennis, whereby multiple on-court sessions are demanded on a daily basis. Therefore, the aim of this study was to investigate the effects of combining CWI, CG and sleep hygiene recommendations on physical, physiological and perceptual recovery following two-a-day, on-court training and match-play sessions.

METHODS

Subjects

Eight trained, professional male tennis players volunteered to participate. Participant characteristics included mean ± standard deviation (SD) age 20.9±3.6 y, body mass 77.6±9.3 kg and stature 183.5±10.2 cm. Of the players, four had international rankings in the top 250, whilst the other 4 were in the process of obtaining an international ranking; though all players competed in 25-30 tournaments per year, routinely performing 2-3 training sessions per day during training phases. All experimentation was approved by the University Ethics in Human Research Committee, with written and verbal informed consent provided following explanation of all procedures.

Design

Following familiarisation with all procedures, participants were matched for age, mass, ranking and perceived skill level to form a pair for the ensuing tennis sessions. As a pair, participants completed two conditions in a randomised, cross-over design of on-court tennis training and match-play. All participants were awake at 06:00 each morning for a standardised testing start time (08:00) at which each pair performed a 90min on-court session of controlled tennis drills led by a trained coach. Following a 3h recovery period (at 14:00), participants then performed a 90min match-play session against the same opponent. All procedures in both conditions were standardised and separated by at least 24h recovery. Respective conditions consisted of 1) a control condition (15-min of passive stretching), or 2) a mixed-method recovery condition (consisting of CWI, CG and sleep hygiene recommendations). Measures of technical performance (shot volumes and error rates), physical performance (accelerometry), physiological (heart rate, blood lactate), sleep quality and quantity and perceptual (mood, perceived exertion and soreness) responses were recorded from each on-court session. Further, counter-movement jump (CMJ) height for lower-body power, and nude mass and urine specific gravity (USG) for hydration status were measured before and after both sessions each day.

Participants abstained from alcohol and intense exercise for 24h prior to, and caffeine 3h before each session. All fluid, food and physical activity were standardised prior to and following each testing session by participants noting consumption and activity in provided diaries and replicating for the ensuing cross-over session. Participants were accommodated in hotel rooms each night to standardise sleeping arrangements and were provided access to the same food services at the hotel to standardise nutritional intake of carbohydrate before and after each session at $4 g \cdot kg^{-1}$ body mass. Environmental conditions for respective sessions were $13 \pm 3^{o}C$ and 40±10% relative humidity.

Methodology

Testing was undertaken ~08:00-10:00 and ~14:00-16:00 each day, as these times represent common training periods for professional players. Each respective on court session involved 1) 90min of coach-led drills (including a 30min warm up)) and 2) 90min of competitive match-play. On-court sessions were conducted on the same Plexi-cushion hard court surface and led by the same coaches who conferred prior to each session to standardise ball feed and timing of drills. Following a standardised warm up, players performed 60min of structured technical training consisting of tennis specific drills (Figure 1) that are often prescribed in technical training of professional players.[1] Following a 3h recovery period, participants then performed a competitive 90min match-play session against the same opponent. Match-play sessions were observed by coaches and scored as per the rules of professional tennis, with participants instructed to replicate match intensities. Furthermore, each drill and match-play session was filmed and later analysed for notation of shot volume, error rates and work to rest ratios.

Following both on-court sessions, participants respectively performed the recovery or control condition. The recovery intervention consisted of 15-min whole-body CWI in a seated position to the suprasternal notch in a plunge pool (Ice Bath, White Gold Fitness, Bedford, UK) of ice-water at 11 ± 2^{o}C.[6,13,16] CWI was immediately followed by wearing full-body (long-sleeve top and full-length lower-body) compression garments (2XU, Melbourne, Australia) that were individually fit to participants based on height and body mass. CG's were worn between the drill and match-play sessions (for 3.0 ± 0.5h) and for 4h after match-play. That night, the sleep hygiene recommendations involved participants retiring to their provided accommodation and creating a low-light, cool environment at 21:00. Specifically, participants ensured all electronic stimulants ie. TV, mobile phones and computers were limited or avoided and excessive light was minimised during the ensuing 30min until 21:30, by which time they had retired to bed in a room at 19 ± 2^{o}C and a light luminescence of 3-8 LUX (Lux Light Meter, Digitech, Sydney, Australia). Further, participants provided their own sleep eye-masks to reduce environmental light during sleep whilst ensuring comfort and familiarity[24]. Conversely, in the control condition players stretched for 15min after each on-court session, were not provided with CWI or compression and were allowed to self-regulate exposure to electronic equipment, pre-bed light (60±12 LUX) and sleeping patterns. The aforementioned sleep hygiene recommendations were based on evidence elite athletes required to wake early for training often incur sub-optimal volume and quality of sleep and that exposure to excessive light and electronic stimuli can retard sleep quality.[9,21] All sleeping arrangements for both conditions were visually observed by the research team to confirm compliance.

Prior to each on-court session, players performed a standardised warm-up consisting of the 5'-5' test[25] to determine heart rate recovery (HRR). The test was performed on a Plexi-cushion hard court in a 20-m shuttle run fashion at a constant-intensity delivered by audio prompts. The reminder of the warm up consisted of 10min of dynamic foot work drills and 5min of hitting. All drill and match-play sessions were filmed by a digital video camera (DSR-PDX10P, Sony, Japan), located 10-m above and 6-m behind each baseline. Footage was downloaded and viewed later to notate for total stroke count, including number of forehands, backhands, volleys, serves; forced and unforced errors, as well as error ratios and rally and rest lengths. Coding was performed using customised software (The Tennis Analyst, V4.05.284, Fair Play, Australia) by a trained analyst with a co-efficient of variation <2%. Furthermore, each player was fitted with a 10Hz GPS unit (v2.0, MinimaxX, Catapault, Canberra, Australia) worn in a customized harness between the scapulae to measure 100Hz tri-axial accelerometery of each on-court session. Accelerometry measures (Player Load) have been reported in other sports as a valid and reliable measure of external load, and is expressed as the square root of the sum of the squared instantaneous rate of change in acceleration in each of the three vectors (X, Y and Z axes).[26] Data was downloaded post-session to calculate Player Load (Logan Sprint v5.0, Catapult, Canberra, Australia).

Before and after each session, nude body mass was recorded (MS3200 Electronic Scales, Charder Electronics, Taichung Hesin , Taiwan) and a mid-stream urine sample was collected to measure USG (Pocket Refractometer, Atago, Japan) to describe hydration status. Further, a 10μl sample of capillary blood was obtained from an earlobe to measure lactate before and after each on-court session and again after the 15min post-session CWI recovery intervention (Lactate Plus, Waltham MA, USA). Heart rate (Suunto Memory Belts, Suunto Oy, Vantaa, Finland) was continuously recorded at 5s intervals for the entirety of each session (including 5’-5’ warm up and after the 15-min intervention) and downloaded to calculate mean heart rate for each session (Suunto Training Manager, Suunto Oy, Vantaa, Finland). Following the warm up and immediately after each on-court session, participants completed a repeated CMJ test to determine mean height from five repeated un-weighted jumps (Jump mat, AXON, Portugal). Following each session, players provided a rate of perceived exertion (RPE; Borg CR-10), whilst perceived muscle and joint soreness, respectively (1-10 Likert scale), were provided before and after each session, after the recovery intervention, at 20:00 each night and then again the following morning (08:00). The Brunel Mood Scale (BRUMS), consisting of four moods with a five point rating scale to assess levels of fatigue and vigour, respectively[27] before each session, at 20:00 each night and then again the following morning (08:00). Finally, players wore an actimetry watch (Rediband, Fatigue Science, Hawaii, USA) to record sleep duration (time in bed, asleep) and quality (efficiency and latency) for the 1 day prior to testing (baseline) and for all days during the study.

Statistical Analysis

A repeated measures two-way ANOVA (condition x time) was performed to determine differences ($P<0.05$) in technical, physiological and perceptual responses between recovery interventions. Further, Tukeys’ post-hoc t tests were conducted to locate differences where main effects were evident. Additionally, effect size analyses (Cohen’s d) were used to determine the magnitude of effect of the recovery protocol (<0.20 trivial, 0.20-0.39 small, 0.40-0.89 moderate, >0.90 large).

RESULTS

As presented in Table 1, there were no significant differences and trivial effect sizes ($P>0.05$;$d<0.10$) for total stroke, respective shot or error counts between conditions for the drill session. However, a moderate effect for increased total stroke count was evident during match-play in the recovery condition (P>0.05; d=0.73), despite no difference and trivial-small effects for error rates between conditions (P>0.05;d<0.30). Interestingly, large effects for an increase in both time in play and shots per minute were evident during match-play following the recovery intervention (P>0.05;d>0.90), whilst there was a large effect for an increased rest time (ie. time not in play) was evident in the control condition (P>0.05;d=0.81). In contrast, Player Load accelerometer values did not significantly differ and showed trivial effect sizes between conditions for either drill or match-play sessions (P>0.05;d<0.20;Table 1). CMJ height was not significantly different and exhibited trivial effects between conditions before and after the drill session (P>0.05;d<0.30); though tended to be higher before match-play in the recovery condition (P>0.05;d=0.90; Table 2).

USG was not significantly different between conditions before drill (1.021±0.006 v 1.023±0.006au) or match-play (1.019±0.008 v 1.015±0.010au for Recovery and Control; P>0.05;d<0.20) sessions; whilst the change in body mass over respective drill (-1.60±0.60 v -1.74±0.65kg) and match-play (-1.35±0.53 v -1.56±0.71kg for Recovery and Control) sessions also was not different between conditions (P>0.05;d<0.30). The HRR following the 5'-5' test prior to each session did not differ and exhibited trivial effect sizes between conditions (P>0.05;d<0.20; Table 2). Similarly, mean heart rate during drill (163±12 v 161±8bpm) or match-play (131±16 v 134±16bpm for Recovery and Control, respectively) sessions did not differ between conditions (P>0.05; d<0.30). However, HR was reduced in the recovery condition following the implementation of CWI after both on-court sessions (P<0.05; d>3.00; Table 2). Blood lactate concentration did not differ between conditions before or after either session (P>0.05; d<0.30; Table 2). While the post-session reduction of lactate following CWI intervention tended to be larger following CWI in the drill session (P>0.05;d=0.80), no differences were evident between conditions following match-play (P>0.05;d<0.30).

RPE did not differ between conditions following the drill (7.3±0.9 v 7.5±0.9au) or match-play sessions (4.3±1.0 v 4.1±0.9au; P>0.05; d<0.20). As presented in Figure 2, perceived muscle and joint soreness did not differ between conditions before the drill session (P>0.05;d<0.30), but. were reduced following CWI (P<0.05) after the drill session, match-play session that afternoon (P<0.05; d>1.80) and remained lower until the next morning following CG and sleep interventions (P<0.05;d>1.30). No significant differences were present between conditions at any time point for BRUMS ratings of fatigue or vigour, respectively (P>0.05, d=1.50; Table 2); though large effect sizes were evident for reduced feelings of fatigue the following morning after the sleep hygiene recommendations.

Sleeping conditions for participants were successfully manipulated to create a low light environment in the recovery condition (8±5 v 60±10 LUX). Large effects for increased sleep duration in the recovery condition were evident with the implementation of the sleep hygiene recommendations (P>0.05; d=2.60; Figure 3). The large effects observed for increased sleep duration resulted from both an increased minutes in bed and minutes asleep (P>0.05; d=2.41). Although no significant differences and small-moderate effects were evident for sleep efficiency in the recovery condition (P>0.05; d=0.79) and sleep latency (time to fall asleep) was not different between conditions (P>0.05; d=0.23).

DISCUSSION

This study reports the effects of a mixture of recovery methods (CWI and CG) combined with sleep hygiene recommendations on recovery from twice a day tennis sessions. The on-court sessions used here represent a standardised bout of drills followed by competitive match-play – the combination of which would be most likely observed as players approach the commencement of tournament or, in the latter stages of a pre-competition training phase. Post-session CWI and CG exhibited large effects for increased CMJ, stroke rates and time in play for the ensuing competitive match-play. Further, post-match CWI and CG reduced perceived soreness, whilst the addition of sleep hygiene recommendations improved sleep quantity and blunted the perception of soreness the next day. Accordingly, the combined use of CWI, CG and sleep hygiene recommendations may benefit athlete recovery following twice-a-day, on-court tennis sessions.

Technical stroke play outcomes are fundamental to tennis performance, although between match comparisons are difficult due to a multitude of factors affecting outcomes.[2,5] In the present study, initial sessions were coach-led and did not differ in volume, type, or error rates of technical stroke play or in accumulated accelerations between conditions; suggesting similar technical and physical loads. Following the use of CWI and CG interventions, large effects for increased total stroke count, shots per minute and time in play were evident in ensuing match-play. Previous research suggests CWI to improve subsequent bouts of cycle ergometery, intermittent-sprint exercise and skeletal contractile function[15,16] due to reductions in physiological load or increased neuromuscular recruitment.[6,12] The present technical outcomes of increased time in play and stroke rates suggest an increase in match-play related activities; perhaps akin to the increased work performed in previous research.[15,12] The notion of recovery interventions increasing match-play engagement may seem counter-intuitive. However, it is proposed that the improved physical/perceptual state resulted in the elongation of point play as players searched for appropriate opportunities to hit winners or force opponents into error, as well as leading to a reduction in the recovery time between points, culminating in increased match-play engagement. However, similar match-play accelerometery between conditions implies no difference in gross physical movement. Given the lack of validation of whole-body accelerometery measures for tennis movement or technical outcomes, such data may lack sensitivity compared to traditional match notation. Regardless, the current findings suggest the use of mixed-method recovery after on-court sessions may increase ensuing match-play engagement, as evidence by increased stroke play per unit of time.

Given the relevance of lower-body peak power to physical and technical tennis performance[3,4] large effects noted for recovery of CMJ at the commencement of match-play is relevant for repeated daily tennis sessions. CMJ was reduced following the drill session in both conditions, though tended to be increased following the recovery intervention for match-play. Previous studies report equivocal findings regarding post-exercise recovery of lower-body power with CWI,[14,15,16] although improved peak isometric torque, sprint speed and peak power with CWI have been reported following prolonged intermittent-sprint activity.[15] Whilst most studies report no discernable effect of CG on post-exercise recovery of peak power,[8,10,14,18] there is evidence for compression therapy to have small positive effects on CMJ performance.[19,20] Though no further mechanistic insight can be provided in the current study, a large effect indicating improved CMJ recovery was observed following CWI and CG that could benefit players requiring multiple daily sessions.

CWI as a recovery modality is proposed to reduce thermoregulatory load, increase intra-thoracic pressure affecting blood volume and reduce interstitial leakage of markers of cellular damage.[6,13,16] Similarly, CG's are proposed to alter distal to proximal intra-muscular pressure gradients to assist venous return and promote muscle metabolite clearance.[14,17] The present study observed no effect of recovery interventions on HR or lactate responses to on-court sessions, though reductions in HR and lactate were evident following CWI intervention. Such a finding is common, likely due to the increased hydrostatic pressure attributable to CWI,[13,14,16] though the comparison of passive rest during CWI to active stretching during control is acknowledged as a limitation. Regardless, these effects seem transient, as HRR, HR, lactate and USG did not differ between conditions prior to the ensuing afternoon match-play session. Hence, any acute alteration to blood volume from CWI (as inferred by HR changes) was not prolonged by use of CG, and is unlikely to relate to large effects noted in improved CMJ or match-play performance observed in the ensuing afternoon session. Of further note, the cool climatic conditions of the present study are also likely to result in tolerable thermoregulatory loads, and hence limit the effectiveness of CWI to improve recovery via reduction of thermoregulatory strain.

The effects of sleep are assumed to be integral to recovery of athletic performance, and whilst it remains under-researched in a sport setting, some evidence suggests sleep volume and quality is restricted by early training start times.[21] The present study presents novel data in a sporting context that simple sleep hygiene recommendations can improve acute sleep quantity in athletes and may additionally assist to improve perceptual recovery of soreness and mood the following day. Sleep is known to have both physiological and cognitive regenerative properties,[22,23,24] and the creation of an environment conducive to sleep provides some evidence that acute post-session sleep quantity can be improved with sleep hygiene protocols. The current protocol served as a practical recommendation (in athletes) of common recommended sleep hygiene practices[9,24]. Specifically, to attempt to create a conducive environment to increase sleep by attempting to invoke earlier melatonin onset, reduce core temperature and limit stimuli that would disrupt sleep onset[9,21]. Although further research is required on sleep hygiene procedures, ensuring earlier bed time and a conducive sleep environment can potentially improve perceptual recovery the next day.

Accordingly, improved perceptual recovery following training and competition, whilst not as objective as performance outcomes, is nonetheless still an important component of athlete recovery.[9,11,28] RPE did not differ between conditions in either session, suggesting limited effect of CWI and CG on internal load. Conversely, although muscle and joint soreness increased following both court sessions, CWI and CG resulted in acute and prolonged reductions in perceived soreness. Individually, the respective recovery interventions are commonly reported to improve perceptual feelings of soreness, fatigue and recovery;[10,11,20] though whether such findings are intervention-related or placebo-induced remain an often debated topic.[18,29] Furthermore, inclusion of an effective sleep hygiene protocol maintained the reduced perception of soreness and fatigue until the following morning. In agreement, recent evidence highlights small but significant associations (r=-0.20-0.27) between perceived fatigue state and total sleep time.[30] Consequently, while the current study may not add further insight on the mechanisms of respective interventions, post-exercise CWI and CG, when further supplemented by improved overnight sleep duration, are successful tools to reduce perceived soreness and fatigue following repeated daily on-court sessions.

In conclusion mixed-method recovery interventions consisting of CWI (15min at 10^{o}C), compression garments (for ~3-4h) used after on-court sessions demonstrated large effects for increased time in play and lower-body power and reduced muscle and joint soreness at ensuing sessions. Further, alongside these interventions, a sleep hygiene protocol (low-light, earlier to bed, 19°C room, sleep with eye-masks), assisted the reduction of muscle and joint soreness the next morning following two-a-day sessions on hard courts. These findings may also be applicable to a range of other athletes required to perform and recover for twice daily training and competition sessions.

Practical applications

- Twice a day on-court tennis sessions result in reduced CMJ performance and increased perceptions of fatigue and soreness.
- Mixed method recovery interventions (CWI, CG and sleep) can reduce perceived soreness and fatigue, whilst assisting performance in tennis specific outcomes of increased shot rate and reduced error rate.
- A sleep hygiene protocol (low light, cool conditions and earlier to bed) can improve acute sleep quantity and may relate to improved perceptual recovery.

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Figure Headings:

Figure 1: Movement and stroke patterns of (A) Box, (B) Bow-tie and (C) Suicide drills.

Figure 2: Mean ± standard deviation for perceived A) muscle and B) joint soreness pre- and post drill and match-play (MP) sessions, after the recovery period (Rec), at 20:00 the night of and 0:800 next morning for recovery and control conditions.

* represents significantly different to Control condition ($P<0.05$)

Figure 3: Mean ± standard deviation for A) duration in bed, B) duration asleep, C) sleep latency and D) sleep efficiency following twice-a-day tennis sessions for recovery and control conditions.

represents large effect ($d>0.90$) compared to Control condition.

Table 1: Mean ± standard deviation of duration, total, forehand (FH) and backhand (BH) stroke counts, forced and unforced error, time in match-play, stroke rate per min and Player Load (PL) sum of tri-axial accelerometry for Drill and Match-play session in Recovery (Rec) and Control (Con) conditions.

Session	Condition	Duration (min)	Stroke count (n)	FH count (n)	BH count (n)	Forced error (n)	Unforced error (n)	Time in play (min)	Shot rate (/min)	PL (au)
Drill 1	*Rec*	9.0±0.6	114±6	84±5	30±2	0±0	23±6		12.2±1.1	74±17
"Box"	*Con*	9.0±0.7	111±10	82±7	29±3	0±0	28±8		11.9±1.2	79±10
Drill 2	*Rec*	9.0±0.9	41±9	57±7	28±12	0±0	16±6		9.4±1.0	81±12
"Bow-tie"	*Con*	9.0±0.7	42±12	57±6	28±9	0±0	15±5		9.1±1.0	20±10
Drill 3	*Rec*	9.0±0.8	100±15	74±13	26±4	0±0	20±6		10.6±1.8	77±13
"Suicide"	*Con*	9.0±0.9	98±12	72±12	25±4	0±0	20±6		10.7±1.5	76±12
Drill 4	*Rec*	20.0±0.9	250±15	160±15	83±11	3±2	24±6		12.4±0.5	162±17
"Cross-court Animal"	*Con*	20.0±0.4	260±26	167±17	88±30	2±2	26±8		12.8±1.2	158±21
Drill 5	*Rec*	8.0±0.4	83±10	36±7	45±7	2±1	13±5		10.0±1.8	9±1
"Recovery"	*Con*	8.0±0.2	80±8	37±5	41±7	2±1	13±5		9.7±1.1	9±1
TOTAL	*Rec*	56.0±2.3	760±100	479±50	259±58	5±2	105±21		13.7±1.8	485±62
	Con	56.0±2.0	790±69	497±20	269±55	4±2	110±18		14.0±1.1	488±62
Match-play	*Rec*	90.0±0.2	375±65[#]	130±25	142±29	5±3	33±11	30±2[#]	4.3±0.7[#]	427±68
	Con	90.0±0.2	334±67	120±30	121±30	5±2	29±10	27±3	3.7±0.7	420±81

[#] represents a large effect size (d>0.90) compared to Control.

Table 2: Mean ± Standard deviation of counter movement jump (CMJ) height, Heart rate recovery (HRR), Heart rate (HR), blood lactate (La^-) and Brunel Mood Scale Fatigue and Vigour feelings for drill and match-play (MP) sessions in Recovery (Rec) and Control (Con) conditions.

	Condition	Pre-drill	Post-drills	Post-Recovery	Pre-MP	Post-MP	Post-Recovery	Next morning
CMJ (cm)	*Rec*	40.0±4.0	39.3±3.2		43.8±3.9$^{\#}$	41.0±4.7		
	Con	39.5±4.0	38.6±6.0		41.6±4.5	39.9±3.8		
HRR (bpm)	*Rec*	65±7			68±11			
	Con	67±12			68±11			
HR (bpm)	*Rec*	49±6	163±14	77±8$^{\#*}$	80±10	126±12	70±9$^{\#*}$	
	Con	49±6	164±9	89±4	82±9	128±17	81±8	
La$^-$ (mmol·L^{-1})	*Rec*	1.8±0.5	6.5 ±3.2	2.1±0.7	1.3±0.4	2.5±1.2	1.7±0.4	
	Con	1.7±0.6	4.7±1.0	2.3±1.4	1.2±0.6	2.1±1.3	1.5±0.6	
Fatigue (au)	*Rec*	9.0±2.0			10.0±3.2		11.0±2.8	8.8±1.9$^{\#}$
	Con	8.5±1.9			9.6±3.5		10.8±3.6	11.4±2.9
Vigour (au)	*Rec*	8.4±3.0			8.9±3.4		8.0±4.0	8.4±3.2
	Con	8.9±3.2			8.1±3.3		7.4±3.5	8.0±3.1

$^{\#}$ represents a large effect size (d>0.90) compared to Control.

* represents a significant difference (P<0.05) compared to Control.

Figure 1: A B

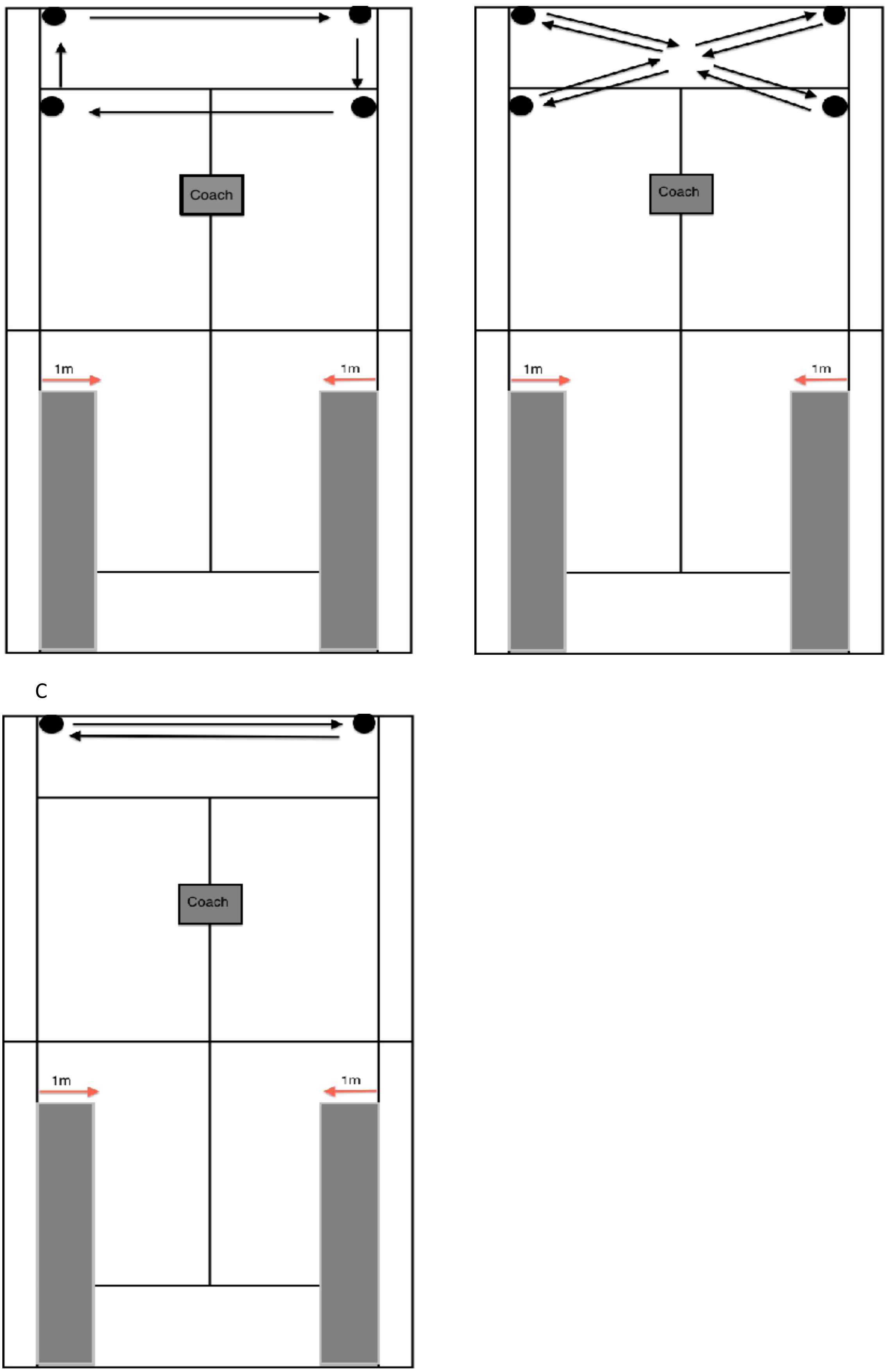


Figure 2:

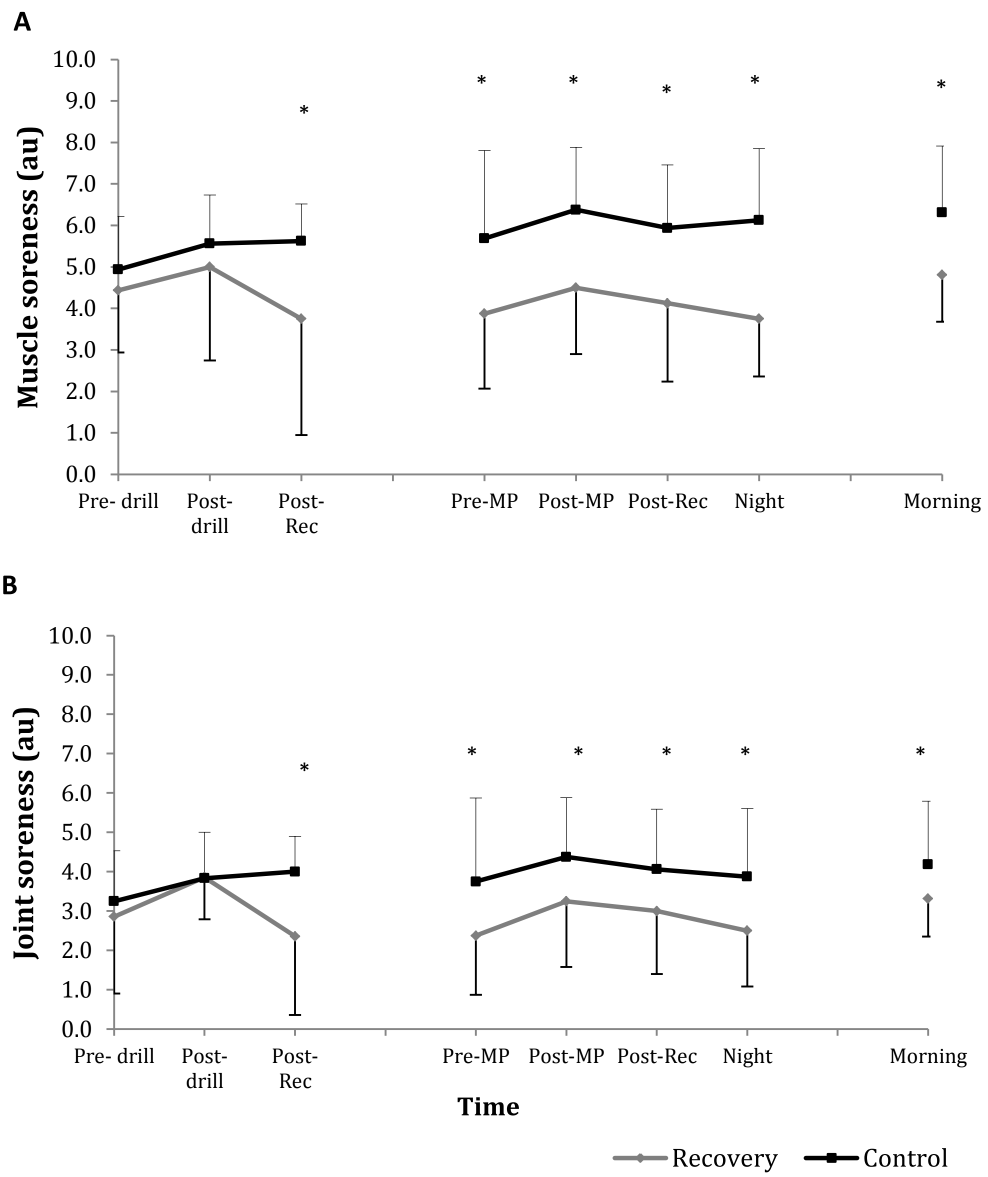
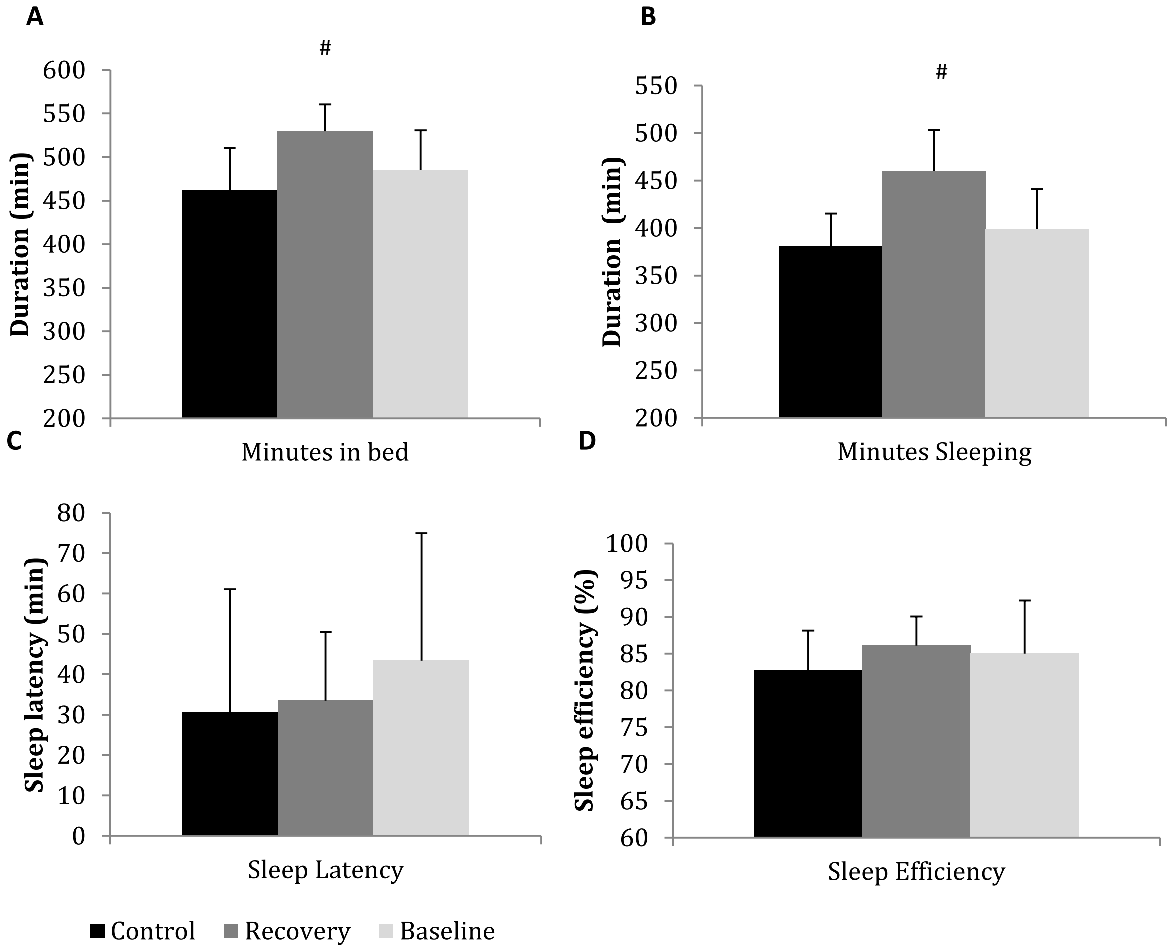

A
Muscle soreness (au)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Pre- drill
Post-drill
Post-Rec
Pre-MP
Post-MP
Post-Rec
Night
Morning
B
Joint soreness (au)
Time
Recovery
Control

Figure 3:


A
#
600
550
500
450
400
350
300
250
200
Duration (min)
Minutes in bed
B
#
550
500
450
400
350
300
250
200
Duration (min)
Minutes Sleeping
C
80
70
60
50
40
30
20
10
0
Sleep latency (min)
Sleep Latency
D
100
95
90
85
80
75
70
65
60
Sleep efficiency (%)
Sleep Efficiency
Control
Recovery
Baseline