

The efficacy of applied re warm up protocols in different team sports: a systematic review

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Abstract

Problem Statement: Passive half-time rest for athletes in team sports could subsequently lead to performance decrements and increased risk of injury. Several studies have shown that active re-warm-up (RWU) protocols could attenuate performance decrements due to passive rest. **Purpose:** This systematic review aimed to critically analyze the effects of RWU protocols in relation to the team sport in which they were evaluated. **Methods:** The research was conducted using four electronic databases (the Web of Science, Scopus, Google Scholar and SPORTDiscus), following the PRISMA guidelines and PICO strategy. Only original articles that evaluated the acute effects of RWU protocols were included in the study. On the contrary, RWU protocols that involved exclusively passive strategies were excluded. **Results:** Out of the 752 relevant studies identified, only 17 met our criteria. The main outcomes were grouped and evaluated in the four different sports: football, team sports, rugby and basketball. The results indicated that there was no consensus on a gold standard protocol that could attenuate most of performance losses provoked by passive rest. All active methods, except for the eccentric exercises that have been shown to be harmful, had beneficial effects on athletic performance compared with passive rest. **Conclusions:** Athletes should enter game prepared for optimal performance, without the need for a transitional phase to regain the warm-up benefits. Therefore, coaches should establish a short RWU protocol, right before commencing a sport activity, including either intense exercises or sport specific movements, to counteract the negative impact of passive rest on subsequent performance in team sports.

Keywords: Re-Warm Up, Half-time Strategy, Subsequent Performance, Passive rest, Team Sports

Introduction

The effect of warm-up (WU) on subsequent sport performance has been investigated over the years (Galazoulas et al., 2012; Otte et al., 2020; Obetko et al., 2020). While the 79% of the WU protocols improved the subsequent performance of the athletes (Fradkin et al., 2010), they also contributed to the reduction of the injury risk (Woods et al., 2007). However, a number of intermittent team sports such as football (soccer), rugby, Gaelic sports (e.g., Gaelic football and hurling), handball and field hockey are played over consecutive periods (typically 30 – 45 min of duration) that are separated by a temporary pause in play at the mid-way point; a period known as half-time which is 10–20 minutes long (Russell et al., 2015).

There are also some other sports in which athletes have to remain inactive after the WU until their entrance to the game. A sport which applies to this case is basketball, in which, according to regulations (FIBA, 2020), a team may use up to 12 players in a game. Seven of them are inactive and seated on the bench at all times during the game (Galazoulas et al., 2012).

The typical passive nature of these periods can lead to decrements in sports performance (Wong et al., 2011) and to increased risk of injury (Hawkins and Fuller, 1996). While performing RWU activities are considered a valuable strategy to avoid reduced sports performance during prolonged periods (González-Devesa et al., 2021), empirical observations highlight that players primarily aim to mentally relax, rehydrate and re-fuel, address injury or equipment concerns, engage in personal reflection and receive tactical instruction and coach feedback (Russell et al., 2015). There are plenty of researches acknowledging that the mental preparation and physiological factors have a significant impact on the player's preparedness and his performance (Bishop, 2003; Abdullah et al., 2016; Menegassi et al., 2018; Obetko et al., 2020). However, time limitations, lack of cooperation with the coach/manager and a perceived negative effect upon the psychological preparations of players have been reported as barriers to the use of active RWUs during half-time period, regardless the fact that practitioners acknowledge that attenuating losses in body temperature impact positively on subsequent sport performance (Towlson et al., 2013).

Numerous studies have reported declines in the amount of high-intensity running and sprinting which are important indicators of performance in players of intermittent team sports, after traditional passive half-time practices in thermoneutral environments (Yanaoka et al., 2018a). Passive recovery during half-time leads to

1.1°C and 2.0°C reductions in core and muscle temperatures respectively (Mohr et al., 2004). Body temperature and countermovement jump (CMJ) in basketball players decreased gradually during rest after standard WU, whereas 10m and 20m run times increased gradually (Galazoulas et al., 2012).

Over time, various researchers gathered the published studies on RWU protocols in order to review the findings. Michailidis (2014) concluded that soccer players cover less distance, especially in high intensity at the beginning of the second half. Although a limited number of studies were reviewed about this aspect, it was obvious that an active RWU can maintain the body temperature and physical performance of soccer players. These findings are in agreement with those of Hammami et al. (2018) who found that the traditional passive half-time period during soccer matches causes temporary impairment in players' physical performance capacity and a soccer-specific activity completed at high-intensity with short-durations may provide an ergogenic aid for subsequent sport performance.

In a general review related to the WU, the post WU and the RWU, Silva et al. (2018) concluded that in transitions longer than 15 minutes between the end of WU and the start of a match or the entry into a game, performing 2-min short-term explosive tasks allowed the recovery of performance levels achieved during the initial WU. Also, in typical ambient conditions (10–30 °C) no rest is recommended during half-time whilst a heated garment that maintains muscle temperature and subsequently the performance of the athlete should be used. Finally, González-Devesa et al. (2021) carried out a broad review analyzing the effects of the RWU strategies during half-time rest periods on team sports. The main results indicated that the RWU protocols are more effective than passive rest in order to improve match activities and passing ability.

However, there is not any review to date which categorizes the RWU protocols according to the sport in which they are applied to. It is necessary to classify the applied methods according to the sports used, as the majority of the researchers and coaches are specialized solely in a sport. Therefore, the aim of this systematic review is to analyze the effects of RWU protocols in relation to the team sport in which they are investigated.

Materials and Methods

Design

Systematic review guidelines were used to conduct electronic research in four databases (Web of Science, Scopus, Google Scholar and SPORTDiscus). The following key words were used in different combinations: “re-warm up”, “half-time strategy”, “intermittent team sport”, “exercise performance”, “subsequent performance”, “sitting”, “team sports”, “soccer”, “football”, “basketball”, “rugby”. The last search was carried out in October 2021.

The research was conducted according to PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines (Moher et al., 2015) and included the PICO strategy (Table 1).

Inclusion and Exclusion Criteria

Studies included to the review had to be written in English and published in peer-reviewed journals. Only original articles which evaluated acute effects of different RWU protocols and describing their outcomes were included in this review. Also, the articles included had to have used repeating measures designs or randomized controlled trials. Finally, there were no restrictions on the team sports or on the athletes.

Review articles, studies which investigated long-term effects and studies which did not included control groups were excluded from the review. RWU protocols which involved exclusively passive strategies (e.g., thermoregulatory factors, survival jackets etc.) were also excluded. Conference proceedings, posters, theses and dissertations were not included in this review.

Table 1: Search strategy and inclusion/exclusion criteria based on PICO (Population, Intervention, Comparison and Outcome)

Databases	Search Terms	PICO	Inclusion Criteria	Exclusion Criteria
Web of Science Scopus Google Scholar SPORTDiscus	• Re-warm up • Half-time strategy • Intermittent team sport • Exercise performance • Subsequent performance • Sitting • Team sports • Soccer • Football • Basketball • Rugby	Population	Sport athletes, healthy people, referees	-
		Intervention	Re-warm up protocols (active) during half-time or rest	Passive protocols
		Comparison	Re-warm up protocols on each team sport	No comparison between structured strategies or control condition with pre/post results
		Outcome	Exercise performance	The outcomes did not consider physical or technical - tactical measures

Study Selection and Data Extraction

Two independent reviewers screened citations and abstracts separately to identify articles which potentially met the inclusion criteria. For the articles initially identified, full text versions were retrieved and independently screened by the two reviewers to determine whether they met the inclusion criteria or not.

The eligible references were subjected to a second audit of the full text based on inclusion and exclusion criteria. Basic details for all eligible articles (authors, year, participants, protocols, evaluation tests, measurements and main results) were collected and organized in a table (Table 2). For this purpose, the RWU protocols were classified according to the sport in which they were applied: football, team sports, rugby and basketball.

Quality Assessment

The risk of bias of each study was assessed by two authors separately. The criteria examined following methods recommended by the Cochrane collaboration (Higgins et al., 2019) were: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other bias. The classifications used were: low risk, high risk and unclear risk (either lack of information or uncertainty regarding the potential for bias). Disagreements were resolved by discussion with a third researcher. The Review Manager Software Version 5.4.1 was utilized to create risk-of-bias graphs (Figure 1 and 2).

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Abade et al., 2017	⬤	?	?	?	+	+	+
Alberti et al., 2014	+	?	?	?	+	+	+
Edholm et al., 2015	⬤	?	?	?	+	+	+
Fashioni et al., 2020	+	?	?	⬤	+	+	+
Lovell et al., 2007	?	?	?	?	+	+	+
Lovell et al., 2011	?	?	?	?	⬤	+	+
Mohr et al., 2004	+	?	?	?	+	+	+
Pociūnas et al., 2018	?	?	?	?	+	+	+
Ramos-Campo et al., 2020	⬤	?	?	?	+	+	+
Russell et al., 2018	+	?	?	?	⬤	+	+
Tong et al., 2019	+	?	?	?	+	+	+
Yanaoka et al., 2018a	?	?	?	?	+	+	+
Yanaoka et al., 2018b	?	?	?	?	+	+	+
Yanaoka et al., 2018c	+	?	?	?	+	+	+
Yanaoka et al., 2020	+	?	?	?	+	+	+
Yanaoka et al., 2021	+	?	?	?	⬤	+	+
Zois et al., 2013	+	?	?	?	+	+	+

Figure 1: Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

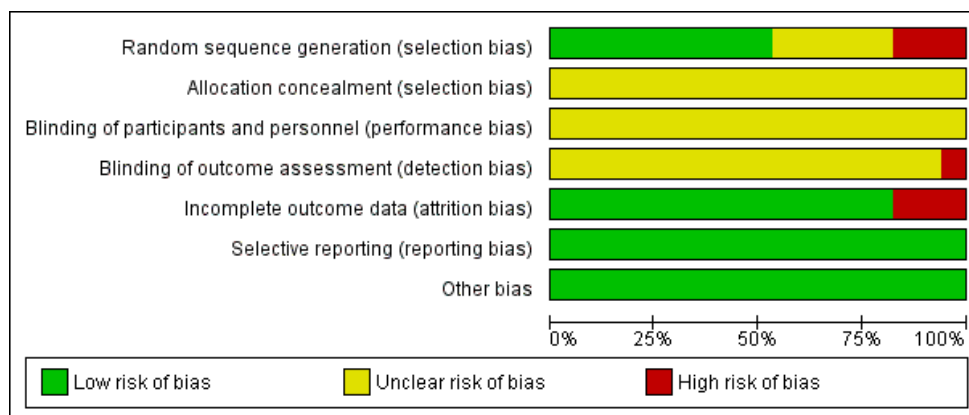


Figure 2: *Risk of bias graph: Review authors' judgements about each risk of bias item presented as percentages across all included studies.*

Results

Search Results

The study selection process is showed in Figure 3. A total of 752 relevant studies were identified from the database research. After excluding duplicates, we screened titles and abstracts of 381 records, and subsequently, 34 articles were retrieved for a full-text assessment. Finally, 17 studies met the inclusion criteria and were included in the systematic review.

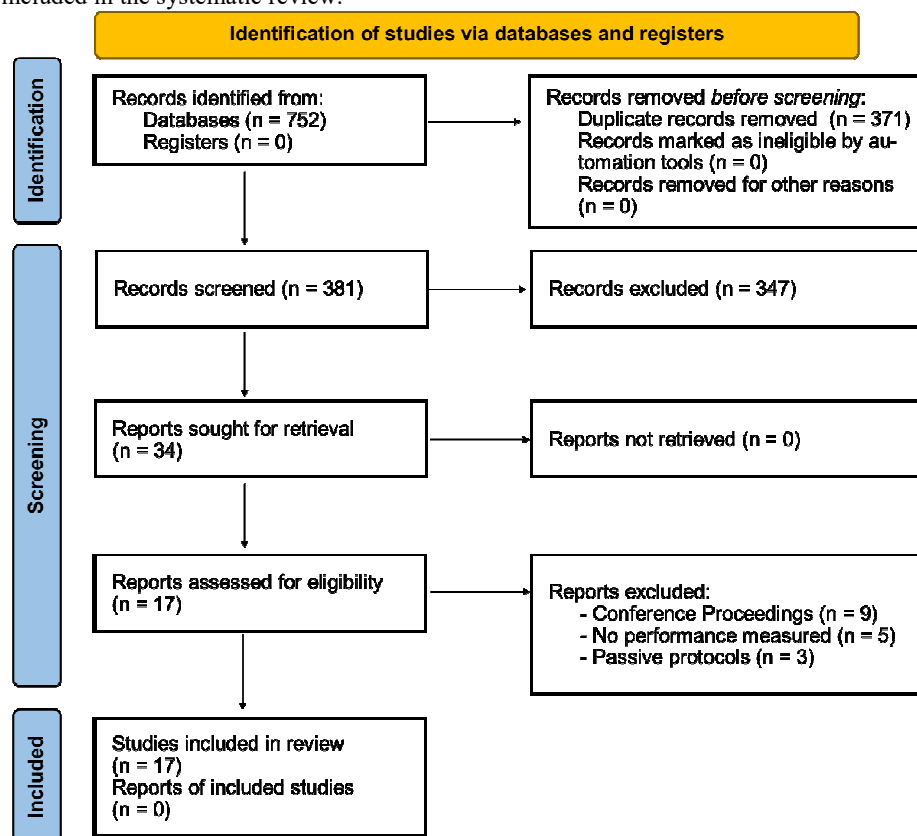


Figure 3: *PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) study flow diagram.*

Study Range and Characteristics

292 male participants were included in the studies in total. The involved participants were either team sport athletes or just active – well trained players. A study was applied to soccer referees. The level of the athletes ranged from amateur to professional and elite. The age of participants across all studies ranged from 16 to 33 years.

Out of the 17 included studies, 11 used a crossover design while two of them were described as counter-balanced studies. In the rest four, even if the procedure was understandable, the design was not clarified by the authors, or it was clarified as merely randomized.

Main Outcomes

The review was grouped into 4 categories: Football (1), Team Sports (2), Rugby (3), Basketball (4). The studies included appear on Table 2, displayed by category and in chronological order.

Table 2: Main characteristics of the studies included in the systematic review on applied Re-Warm Ups on team sports.

Authors (Year)	Participants	RWU Protocols	Evaluation Test/Sport	Measurements	Main Findings
Mohr et al. (2004)	25M Competitive football players	Control; 7' moderate intensity RWU	Friendly football match	T_{m} ; T_{c} ; SP	- Pre 2nd Half: T_m RW > T_m CON ($2.1 \pm 0.1^{\circ}\text{C}$) - Onset 2nd Half: SP at RWU ~ PRE_{value}; SP at CON < PRE_{value} (2.4%)
Lovell et al. (2007)	7M Professional soccer players	Control; 7' PH; NSAH Cycling 7-70% HR; SSAH 7-70% HR	Two Intermittent field tests of 16,5 min and HT 15 min.	SSEP; Bangspo Field Test; HR; T_c	- Active RWUs: $\uparrow$ HR, T_c and ~SSEP compared to CON ($p < 0.01$) - CON: $T_c \downarrow 0.97 \pm 0.29^{\circ}\text{C}$ - NSAH: $\uparrow T_c$ compared to CON ($p < 0.01$)
Lovell et al. (2011)	10M Semi-professional football players	Control; IAE; WBV	SAFT ⁹⁰ interceded by a 15-min HT	10-m sprint; CMJ; CQ; CH; EH; Isokinetic peak torque; HR; Gas measurements; T_m	- Onset 2nd Half: SP, CMJ & EC $\downarrow$ PRE_{value} in CON ($p \leq 0.05$) - Onset 2nd Half: SP, CMJ & EC ~ PRE_{value} in WBV & IAE ($p > 0.05$) - Pre 2nd Half T_m: IAE > CON & WBV ($p \leq 0.01$)
Zois et al. (2013)	8M Amateur soccer players	Control; 3' SSG; 5RM Leg Press	2x26-min IAP on a non-motorized treadmill, interspersed by 15-min	CMJ; RSA; LSPT; 5RM Leg Press; [Lac] ⁺ b; HR; Perceptual measures (perceived effort, soreness, and fatigue)	5RM $\uparrow$ flight-time to contraction-time ratio compared to SSG (9.8%) and CON (9.4%); - RSA $\uparrow$ in 5RM, peak velocity, mean velocity, and acceleration were $\uparrow$ 4, 3, and 18% respectively; - LSPT $\uparrow$ in SSG (6.4%) compared with PRE_{value}.
Edholm et al. (2015)	22M Professional soccer players	Control; Low intensity RWU	Two soccer matches	10-m sprint; CMJ; Time-motion analysis	- Pre CON - Post CON: SP & CMJ $\downarrow$ 2,6% & 7,6% - Pre RWU - Post RWU: SP ~ & CMJ $\downarrow$ 3,1% - First 15' 2nd half: ~High-intensity running in CON & RWU; RWU Defensive High-intensity running < CON ($p < 0.01$); RWU ball possession > CON
Yanaoka et al. (2018c)	10M Soccer referees	Control; RWU (13' Intermittent Exercise)	Loughborough Intermittent Shuttle Test and Yo-Yo IR1 period interspersed by 15-min HT.	Yo-Yo IR1 performance; blood glucose; FFAs; TGs; CK; lactate concentrations; RPE; mean HR; HRmax	- Yo-Yo IR1 Performance: RWU > CON ($p \leq 0.05$) - Between trials: ~ mean HR and HRmax, blood glucose, FFA, TG, CK, and lactate concentrations - PRE post intervention: RWU > CON ($p \leq 0.05$)
Abade et al. (2017)	22M U19 Elite football players	Control; ECC; PLY; RCOD	Football WU	AJ; CMJ; 10-m; 20-m	- VJ & SP $\uparrow$ in PLY & RCOD - VJ $\downarrow$ in ECC ($\pm 90\%$CL)
Fashioni et al. (2020)	10M Amateur soccer players	Control; 3' RWU (Ballistic and Plyometric exercises)	60 min of a SSEP (4 x 15- min periods with a 15-min HT between 3 rd and 4 th period)	5, 10, 20-m sprint; SJ; CMJ; PlayerLoad TM ; perceived muscle soreness; RPE	- Pre 2nd half: SP 20m. (CON: 3.42 ± 0.20s; RWU: 3.32 ± 0.12s), SJ (CON: 26.96 ± 5.00cm; RWU: 30.17 ± 5.13cm) & CMJ (CON: 28.15 ± 4.72cm; RWU: 31.53 ± 5.43cm) - Between trials: ~ 5m, 10m, perceived muscle soreness & PlayerLoadTM - Pre 2nd half RPE: RWU > CON (~2 a.u)
Yanaoka et al. (2018b)	13 Healthy men	Control; 7' 70% HRmax; 3' 70% HRmax	40-min intermittent exercises, 15-min HT and 40-min CISP.	CISP; HR; Gas measurements; Muscle oxygenation; RPE; [Lac] ⁺ b;	- Mean Work initial 10': CON < 3' RWU < 7' RWU (CON: 3638 ± 906 J, 7' RWU: 3808 ± 949 J, 3' RWU: 3827 ± 960 J) - Initial 10' (change in oxygenated hemoglobin concentration, oxygen uptake, carbon dioxide production, and respiratory exchange ratio): Both RWUs > CON ($p < 0.05$) - RPE after HT: Both RWUs > CON

(p<0.05)					
Yanaoka et al. (2018a)	11 Healthy men	Control; 3' RWU 30% VO ₂ max; 3' RWU 60% VO ₂ max	40-min intermittent exercises, 15-min HT and 20-min CISP	CISP; HR; Gas measurements; Muscle oxygenation; EMG; T _{sk} ; Estimated T _{ms} ; RPE	- Mean Work & EMG: 60% & 30% RW> Control (p<0.05) - T_{ms}: 60% RWU > 30% RWU > CON (p<0.05)
Tong et al. (2019)	9M College team sports athletes	Control; RWU (4' CM exercises with inspiratory load)	Simulated team-sport IEP in two phases, on a non-motorized treadmill, interspersed by a 15-min HT	RSA; IEP; SEPT; HR; Muscle Oxygenation; T _{sk} ; PImax; RPE; RPB	- Post P1: PImax: -8.1%, SEPT: -29.7% (p<0.05) - Pre P2 (CON): PImax: -6.4%, SEPT: -19.0% (p<0.05) - P2: RSA (CON): peak vel.: -2.3%, mean vel.: -2.1% - Pre P2 (RWU): PImax: -0.9%, SEPT: -3.3% (p<0.05) - P2 RSA (RWU): peak vel.: +3.0%, mean vel.: +2.0% (p<0.05)
Yanaoka et al. (2020)	12M Active males	Control; 3' 30% VO ₂ max; 1' 90% VO ₂ max	40-min intermittent exercises, 15-min HT and 10-min CISP	CISP; HR; Gas measurements; Muscle oxygenation; EMG; T _{sk} ; Estimated T _{ms} ; RPE	- Post HT Mean Work: RWU30 & RWU90 > CISP (CON: 3539±698 J; RWU30: 3724±720 J; RWU90: 3739±736 J; p<0.05) - Post HT Mean EMG: RWU30 > CON - Post HT initial 30s Oxygenated hemoglobin: RWU90 > CON (p<0.05)
Yanaoka et al. (2021)	12M Amateur team sports players	Control; 1' running 90% VO ₂ max	Two LIST of 45-min and 15-min HT	LIST; HR; T _{gas} ; EMG; RPE	- SP At 4th period: RWU > CON (2.4%, p=0.002) - HT T_{gas}: RWU > CON (0.5 °C, p=0.01) - Mean HR After HT: RWU > CON (4bpm, p=0.016) - Neuromuscular Efficiency after HT: RWU > CON (9%, p=0.048)
Russell et al. (2018)	20M Professional rugby players	Control; 15' rest; 15' Passive with survival jacket; 7' Active RWU; 8' Passive with survival jacket and 7' Active RWU (Combined)	Two RSSA and HT 15'	T _{sk} ; CMJ;PPO; RSSA	- T_{sk} Reductions: CON (0.62 ± 0.28 °C) > Act (-0.17 ± 0.09 °C) > Com (-0.03 ± 0.10 °C). - PPO (CMJ) Reductions: Con > Act > Com (p<0.001) - RSSA2: Com (p<0.001) > Act (p=0.002) > CON
Ramos-Campo et al. (2020)	10M Elit rugby players	RN; RH; AN; AH	15-min WU and 15-min RWU	CMJ; 20-m Sprint; RSA; T _{sk} ; muscle oxygenation; [Lac] ⁻ lb; RPE	- Post RWU T_{sk}: AN and AH > RN and RH (p=0.016) 20m Sprint & CMJ: AH > RN (p=0.02) - Mean RSA: AH < RN & RH (p=0.008) - SaO₂: AH > RN, RH & AN (p = 0.021) - Hb: AH > RN (p = 0.042) - Blood Lactate: RN & AN > AH (p=0.007)
Alberti et al. (2014)	81M Young basketball players	Continue Playing; SIT; STA; TAP; LBM	20 minutes under different conditions	CMJ; SL	- CMJ: CON & STA ~ PREvalue (p>0.05) - CMJ (SIT, TAP & LBM): T1 > T2 (p<0.001) 2' min reactivation at SIT ↑ SL (p < 0.01), albeit it was lower 3.92% than T1
Pociunas et al. (2018)	10M College basketball players	Aerobic; Aerobic + PAP; Aerobic + PAP + Stabilization	Simulated basketball game	CMJ	- Between Pre RWU and Post RWU CMJ ↓: Aerobic > Aerobic + Stab. + PAP > Aerobic + PAP - Post RWU CMJ: ↓ in Aerobic (p<0.05)

<: Lower; >: Greater; ↑: Increment; ↓: Decrement; ~: Similar Results or Maintenance; AH: Active in Hypoxia; AJ: Abalakov Jump; AN: Active in Normoxia; CH: Concentric Hamstring Strength; CISP: Cycling Intermittent Sprint Protocol; CK: creatine kinase; CL: Confidence Limit; CM: Core Muscle; CMJ: Counter Movement Jump; CON: Control Group; CQ: Concentric Quadriceps strength; ECC: Eccentric; EH: Eccentric Hamstring strength; EMG: Electromyogram; F: Female; FFAs: free fatty acids; Hb: hemoglobin; HR: Heart Rate; HT: Half Time; IAE: Intermittent Agility Exercise; IAP: Intermittent Activity Protocol; IEP: Intermittent Exercise Protocol; [Lac]⁻lb: Blood Lactate concentration; LBM: Lower Back Mobilization; LSPT: Loughborough Soccer Passing Test; M: Male; NSAH: Non-Specific Active Heating; P1/P2: Phase 1/2; PAP: Post Activation Potentiation; PH: Passive Heating; PImax: Maximal Inspiratory Pressure; PLY: Plyometric; PPO: Peak Power Output; PREvalue: Value Prior to Intervention; RCOD: Repeated Changes of Direction; RH: Rest in Hypoxia; RM: Repetition Maximum; RN: Rest in Normoxia; RPB: Rating of Perceived Breathlessness; RPE: Rating of Perceived Exertion; RSA: Repeated Sprint Ability; RSSA: Repeated Shuttle Sprint Ability Test; RWU: Re-Warm Up; SAFT90: 90-min Fixed-intensity Soccer Simulation; SaO₂: Muscle O₂ Saturation; SEPT: Sport-specific Endurance Plank Test; SIT: Sitting; SJ: Squat Jump; SL: Stiff Leg Test; SP: Sprint Performance; SSAH: Soccer-Specific Active Heating; SSEP: Soccer Specific Endurance Test; SSG: Small Sided Games; STA: Standing; T1/T2: Time Point; TAP: Foot Tapping; T_{sk}: Core Temperature; T_{gas}: Gastrointestinal temperature; TGs: Triglycerides; Tm: Muscle Temperature; T_{sk}: Skin Temperature; T_{ty}: Tympanic Temperature; VJ: Vertical Jump; WBV: Whole Body Vibration; WU: Warm UP

Football

In all football surveys except for one, the RWU protocol was applied during the half-time period to the players who were already playing. This occurred because substitutes do not perform WU prior to the beginning of the match, but only a few minutes earlier in case they are about to enter the game. In the study that RWU was not performed on the half-time, it took place during the passive rest after the end of the WU and before the beginning of the game (Abade et al., 2017).

Regarding the RWU protocols applied in half-time, excluding the control groups which normally performed passive rest, 11 different active methods were applied in total. The review of them is presented in chronological order.

In the first study, Mohr et al. (2004) examined the correlation between quadriceps muscle and sprint performance after half time. The RWU protocol contained 7' low to moderate exercise and resulted in higher muscle and core temperature at the beginning of the second half ($2.1 \pm 0.1^{\circ}\text{C}$ and $0.9 \pm 0.1^{\circ}\text{C}$ respectively) at RWU than CON. Also, at this moment, the sprint performance was reduced by 2.4% at CON, while it remained unchanged at RWU.

In a later study, Lovell et al. (2007) investigated the effect of active and passive RWU strategies on cardiovascular (heart rate) and thermoregulatory stress and on the second-half soccer specific endurance performance. As only the active methods were considered in this review, the two active RWU protocols were performed between minutes 7 and 14 of the half time interval. The first one involved 7-min cycling on an ergometer at an intensity that elicited 70% HRmax (NSAH) and the second one was composed of repeated agility sprint drills working at a work to rest ratio that elicited 70% HRmax (SSAH). The results showed that soccer specific endurance performance was maintained after performing the active methods with respect to the passive rest ($p < 0.01$). Moreover, the core temperature decreased to CON by $0.97 \pm 0.29^{\circ}\text{C}$ but SSAH did not attenuate this decrease ($p > 0.01$), whereas NSAH increased it in respect to CON ($p < 0.01$).

In another study, Lovell et al. (2011) used two alternative RWU methods, the whole-body vibration (WBV) and intermittent agility exercises (IAE). At the beginning of the second half, the effect of rest in CON was detrimental in all measures (sprint, CMJ and eccentric hamstring peak torque) compared to the end of the first half ($p \leq 0.05$). On the contrary, there was no significant change in these parameters post WBV and IAE protocols ($p > 0.05$). Regarding the vastus lateralis temperature, there was a significant loss for CON and WBV in the half time ($1.5 \pm 0.4^{\circ}\text{C}$ and $1.1 \pm 0.4^{\circ}\text{C}$ respectively) compared with IAE ($0.5 \pm 0.4^{\circ}\text{C}$).

Zois et al. (2013) examined two different RWU methods on soccer players during half time rest in an intermittent activity protocol (IAP). The first group performed a 5RM leg-press while the second group a 3-min small-sided game (SSG). The 5RM leg-press RWU improved physical performance, while a SSG RWU enhanced skill execution. Specifically, flight-time to contraction-time ratio and relative-maximum rate-of-force development was greater in the 5RM condition following the second IAP compared to SSG and CON. Finally, repeated sprint ability (peak velocity, mean velocity and acceleration) was improved in the 5RM RWU (4, 3, and 18 % respectively) whereas the SSG method improved the Loughborough Soccer Passing Test (6.4 %; ES: 0.6 ± 0.8).

Seven minutes of low-moderate intensity jogging and light calisthenics at $\sim 70\%$ of HRmax were used as RWU method in a soccer half time interval by Edholm et al. (2015). The results indicated that 10-m sprint and CMJ were reduced by 2.6% and 7.6% respectively during the half-time period in CON, while sprint performance was maintained and the decrement in CMJ (3.1%) was lower after RWU. Also, less defensive high-intensity running was observed after RWU than CON (0.14 ± 0.06 vs 0.22 ± 0.07 km). RWU group had more possession of the ball in the beginning of the second half.

A different approach of the RWU protocols was assessed by Abade et al. (2017). Concretely, RWU was performed during passive rest, between the end of the WU and the start of the game. Three different protocols were performed by the participants: eccentric (ECC), Plyometric Exercises (PLY) and Repeated Changes of Direction (RCOD). The main results indicated that the RCOD and the PLY had beneficial effect on the vertical jump and sprint performance compared to the CON group, while the ECC's effect was detrimental to the vertical jump.

A unique study on soccer referees was conducted by Yanaoka et al. (2018c). The RWU method applied to the referees involved a cycle of 13 minutes of duration in which the referees repeated 2.15 minutes of seated rest, followed by 2.15 minutes of running at 70% HRmax. Post RWU, the Yo-Yo IR1 performance was higher than in the CON ($3,095 \pm 326$ vs. $2,904 \pm 421$ m). No significant changes were identified between the two trials in mean HR, the HRmax, blood glucose, free fatty acids, triglycerides, creatine kinase and lactate concentrations. As for the rating of perceived exertion after the half time, it was higher in RWU group than in the CON.

The most recent study performed on soccer players was the one of Fashioni et al. (2020). In this study, the RWU protocol had beneficial effects in comparison with the CON in 20-m sprint performance (CON: 3.42 ± 0.20 s; RWU: 3.32 ± 0.12 s), squat (CON: 26.96 ± 5.00 cm; RWU: 30.17 ± 5.13 cm) and CMJ height (CON: 28.15 ± 4.72 cm; RWU: 31.53 ± 5.43 cm). On the contrary, there were no significant differences on 5-m and 10-m sprint performance, perceived muscle soreness and PlayerLoadTM. However, as on the aforementioned study, the rating of perceived exertion was higher following the RWU.

Team Sports

The following studies had a wider application as they were carried out with the participation of athletes from various team sports (soccer, handball, basketball and lacrosse). The RWU protocols were applied over the half time interval which took place between two intermittent exercise protocols.

The first study was conducted by Yanaoka et al. (2018b). In this research, 13 healthy men participated in a randomized crossover designed study and performed two 40-min intermittent exercises separated by a 15-min half time. Two active RWU methods were applied and consisted of 7-min of cycling at 70% of HRmax and 3-min of cycling at 70% of HRmax. The major findings indicated that in the initial 10 minutes of the cycling intermittent sprint protocol (CISP) the mean work was higher in both RWU groups (CON: 3638 ± 906 J, 7-min RWU: 3808 ± 949 J, 3-min RWU: 3827 ± 960 J) as well as the change in oxygenated hemoglobin concentration, oxygen uptake, carbon dioxide production and respiratory exchange ratio. Once again, the rating of perceived exertion was higher following the RWU.

In a later study, Yanaoka et al. (2018a) applied two different RWU protocols. The first one involved 3-min of moderate-intensity RWU (cycling at 60% of VO_2max) and the second one 3-min of low-intensity RWU (cycling at 30% of VO_2max). The mean work and electromyogram amplitude during the sprint in the CISP were higher in both RWU trials than in the control trial ($p < 0.05$). Muscle temperature at 60 minutes (15 post the end of the half-time) was higher in the 60% RWU trial than in the control and 30% RWU trials ($p < 0.05$). Finally, the mean change in oxygenated hemoglobin concentration during active recovery at the first 10 minutes of the second half tended to be higher in both RWU trials than in the control trial ($p = 0.06$).

Another approach of RWU was examined by Tong et al. (2019). The aim of their research was to assess a RWU which included 4-min core muscle exercises followed by inspiratory loaded breathing and 11-min passive recovery. The outcome was that restoration of inspiratory and core muscles function was accelerated ($p < 0.05$) and this was associated with improved repeated-sprint ability (peak velocity: +3.0%, mean velocity: +2.0%). However, the changes in the anterior thigh muscle perfusion following the RWU exercises were not different from those in passive rest ($p > 0.05$).

Finally, two more studies were conducted in an attempt to reduce the necessary RWU time by increasing its intensity in order to make it easier to apply during the half time without the athletes being deprived of hydration, recovery from injuries and receiving instructions from their coaches. Yanaoka et al. (2020) evaluated two RWU protocols which consisted of 3-min RWU at 30% of VO_2max and 1-min RWU at 90% of VO_2max . The mean work during sprint for the CISP was significantly higher in both RWU trials than in the CON trial (CON: 3539 ± 698 J; RWU30: 3724 ± 720 J; RWU90: 3739 ± 736 J) and in general, RWU protocol, irrespective of whether it comprised 1-min at 90% of VO_2max or 3-min at 30% of VO_2max , increased the subsequent intermittent sprint performance. Similar results were shown on a later study by Yanaoka et al. (2021) in which the effect of running for 1-min at high-intensity (90% VO_2max) was investigated. To be more specific, the RWU improved sprint performance (2.4%), core temperature (0.5°C), muscle activation (12%), and heart rate (4 bpm) in the initial stage of the second half of the Loughborough Intermittent Shuttle Test.

Rugby

Although rugby is one of the most renowned sports globally, to our knowledge, only two studies have focused solely on its RWU methods during the half time interval. The first one was the study of Russell et al. (2018) on which four different RWU protocols were applied. Out of the four protocols, the passive strategy was not taken into consideration in the present review. In the rest two, players either performed a 7-min RWU after 8-min of rest (Active) or wore a survival jacket for 8-min before performing a 7-min RWU (Combined). The 7-min RWU consisted of 3-4 min of low passing between teammates which was followed by 3-4 min of medium intensity jogging and multi-directional ball skills. All half-time interventions attenuated reductions in Tcore ($0.62 \pm 0.28^\circ\text{C}$) observed in Control (Active: $-0.17 \pm 0.09^\circ\text{C}$; Combined: $-0.03 \pm 0.10^\circ\text{C}$) but Combined preserved Tcore the most. All half-time interventions attenuated the $385 \pm 137\text{W}$ reduction in Control Peak Power Output (Active: $-83 \pm 72\text{W}$; Combined: $+10 \pm 52\text{W}$), with best PPO maintenance in Combined. Also, there was a significant difference in the sprint times in the Repeated Sprint Test post half time between Combined ($6.74 \pm 0.21\text{s}$) and Control trial ($6.85 \pm 0.04\text{s}$).

Ramos-Campo et al. (2020) examined the effect of hypoxia. The participants performed rest in normoxia (RN), rest in hypoxia (RH), activity (4×5 jumps/15 s) in normoxia (AN) and activity in hypoxia (AH). Compared to passive strategies (RN and RH), tympanic temperature ($p = 0.016$) was improved in active RWU protocols (AN and AH). Moreover, CMJ ($p = 0.037$) and 20-m sprint performance ($p = 0.02$) was better in AH than in RN. The same was identified on mean RSA ($p = 0.008$) which was better in AH than in RN and RH. Finally, blood lactate concentration was higher after RN and AN protocols than after AH ($p = 0.007$) while muscle O₂ saturation ($p = 0.021$) and total Hb were higher ($p = 0.042$) after AH than after the other three conditions.

Basketball

Not only do the basketball coaches have to deal with the passive rest of the players during the half time but also during the game. However, more studies on basketball players are needed as information is limited.

The aim of Alberti et al. (2014) was to evaluate the effect of prolonged sitting on the vertical jump of young basketball players. The four conditions in which the players were underwent were: control – continue playing (CON), sitting (SIT), standing (STA), tapping (TAP) and lower back mobilization (LBM). Following the 20-minute seated period, the SIT group resumed activity for two minutes, in order to assess the athletic condition of the reserves when they enter the court. The results showed that neither the playing nor the standing players showed significant differences in vertical jump capacity ($p>0.05$), while the jump height significantly decreased in all seated players ($p<0.001$). An important outcome of this research was that the SIT group, after the 2-min reactivation, improved significantly their Stiff Leg test scores ($p<0.01$) approaching the post WU level of performance, whilst they were 3.92% lower than at the first measurement.

A second study performed on basketball players was the one of Pociunas et al. (2018), in which the acute effects of different half time RWU methods on vertical jump height were investigated. The three RWU protocols which were applied to the players were: aerobic, aerobic + post-activation potentiation exercises and aerobic + post-activation potentiation + stabilization exercises. The main outcome was that the least decrease in CMJ height was observed after aerobic type RWU with post-activation potentiation exercises while the greatest reduction was observed in aerobic type ($p<0.05$).

Discussion

This systematic review aimed to present and analyze the effects of the RWU protocols applied on different team sports, in order to group studies that have been performed to date on each sport separately. Using the results of this review, interested researchers and coaches will be able to gather data relevant to their sport and either take the research to the next level or apply a RWU protocol to a group of athletes in order to enhance their performance. Even if there is no consensus on a gold standard RWU protocol or on the protocol that can attenuate most of the losses provoked by passive rest, all active methods, except for the eccentric exercises which have been showed to be harmful, had beneficial effects on the athletic performance in comparison with the passive rest.

Muscle and core temperature have been proved to be crucial factors on performance in football. Mohr et al. (2004) and Lovell et al. (2007) concluded that the temperature is significantly related to the athletic performance, as the lower the temperature is the worse results the athletes get, and this can be reversed by attenuating the core and the muscles temperature reduction. Moreover, it seems that even the shortest RWU protocols (e.g. duration of 3 minutes) can have beneficial effects on the subsequent performance (Zois et al., 2013 and Fashioni et al., 2020) provided that the intensity is appropriate and does not induce additional physiological fatigue compared with seated rest. This can be significant when it comes to the practical application during real games.

The CMJ has also been measured by many researchers as it is an indicator of explosive ability of lower limbs. A 5RM RWU can enhance the subsequent CMJ performance (Zois et al., 2013) compared to passive rest during half time as well as intermittent agility exercise and whole-body vibration (Lovell et al., 2011), low – moderate intensity jogging and light calisthenics (Edholm et al., 2015), plyometrics and repeated changes of directions (Abade et al., 2017) and ballistic exercises (Fashioni et al., 2020).

Even though most of articles have been referred to football, an increasing number of studies involve players from other team sports such as basketball, rugby, handball and others, provided that the same interval applies on half time. Yanaoka et al. (2018b) concluded that a 3-min RWU with cycling at 70% HRmax can be as effective as a 7-min RWU of the same intensity in optimizing subsequent intermittent sprint performance. Even a 1-min running at 90% of VO_2max after a 14-min seated rest has been proven to be beneficial for sprint performance, core temperature, muscle activation, and heart rate in the second half in team sports (Yanaoka et al., 2021). On the other hand, Tong et al. (2019) suggested that a brief inspiratory-loaded core muscle exercise protocols appears to be effective as it improves second half repeated-sprint performance and core function of players in team sports.

As far as the studies which have been conducted solely including rugby players are concerned, only two met our inclusion criteria. Russell et al. (2018) suggested a combined strategy (8-min of passive heating with survival jackets and 7-min of active RWU) which improved peak power output and initial sprint performance in subsequent exercise while it also attenuated significantly the loss of the core temperature (-0.03 ± 0.10 °C). Ramos-Campo et al. (2020) examined an innovative method and found out that rugby players who were submitted to an active RWU under hypoxic conditions improved mean Repeated-Sprint Ability performance and achieved a significantly faster 20-m sprint, higher jump performance and lower mean muscle O₂ saturation than in the rest condition in normoxia. The aforementioned strategies can be beneficial for rugby players, whilst their applicability might be inconvenient and non-affordable.

Considering studies conducted in basketball, few of them have been executed to date as well. Alberti et al. (2014) confirmed that remaining seated for a given period of time has a negative effect on the benefits of WU

and decreases the vertical jump performance. He also found out that two minutes is nearly sufficient to recover post-WU performance levels. In a most recent study, Pociunas et al. (2018) concluded that half-time RWU with aerobic and PAP exercises was more effective provided that the CMJ performance was impaired the least comparing with other two RWU regimens.

Finally, some limitations of the present systematic review should be acknowledged. Provided that there is a limited number of studies investigating the RWU effects, it was necessary to evaluate all kind of levels. Moreover, lack of women participation in RWU protocols exists to date. Other than that, there was no similarity on the protocols applied among the studies and therefore, it was difficult to compare them. There is need for more research on sports other than football such as basketball where players can remain seated for longer than 15 minutes.

Conclusion

Even though most of the studies have been conducted on football, some useful conclusions can be drawn for all team sports, in which players are forced to remain passive for an extended period of time. According to the results of the aforementioned studies, passive rest for a prolonged time should be avoided. Coaches can establish a short RWU protocol, right before the commencement of the sport activity, including either intense active exercises or sport specific movements. Athletes should enter the game prepared for optimal performance, without need for a transitional phase to regain the WU benefits. Otherwise, reduced athletic performance might be crucial for the outcome of game or to even increase the injury risk. Therefore, it seems essential that the coaches and the players be educated on the RWU benefits.

Disclosure statement

The authors report there are no competing interests to declare.

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