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Original Research

Heart Rate Intensity in Female Footballers and its Effect on Playing Position based on External Workload

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ABSTRACT

Introduction

Female football is the world's fastest developing sport, and due to the rise in magnitude, female football, of all levels, must embrace scientific applications allowing an increase in performance through training, technique, and preparation.

Purpose

The purpose of the study was to examine the physiological external workload, of amateur female footballers, across varying heart rate intensities, as well as, interpret fatigue between each half of the Soccer-Specific Aerobic Field Test ($SAFT^{90}$) protocol.

Methods

A sample of n=24 amateur female football players (mean±SD; age: 20.7±4.0 years; stretched stature=165.6±5.8 cm, body mass=58.1±4.7 kg) were recruited during the 2016/2017 competitive season. Maximum heart rate (HR_{max}) values were determined using the Yo-Yo intermittent recovery level 1 (Yo-Yo IR Level 1) with the $SAFT^{90}$ protocol used to interpret the physiological and mechanical demands displayed during football match. A one-way analysis of variance was applied to determine the differences between each position (defenders, midfielders, and forwards) with the level of significance set at alpha level $p<0.05$.

Results

There were statistically significant differences between each position and total external workload (F(df:23)=9.156; ($p<0.05$), in addition to average heart rate (HR) across 90-minutes (F(df:23)=22.317; ($p<0.05$). Statistical significance determined differences between each position and the duration of time spent within the prescribed HR intensity zones, including zone 1 (<70% HR_{max}), zone 2(70-85% HR_{max}) and zone 4(90-95% HR_{max}) across the $SAFT^{90}$. The total distance all players completed across the 90-minutes was 10913.7±1076.7 m, whereas the shortest external workload (10020.4±1086.6 m) was completed by defenders and largest (11781.9±324.7 m) by midfielders. The average heart rate of all player's was 161.1±14.7 bpm^{-1} resulting in a mean intensity of representing 81% HR_{max}.

Conclusion

Midfielders spent the largest proportion of time between zone 2 and zone 4. Based on these results, coaches are able to determine which type of physiological profile is needed for a specific positon and use this information to design specifically prescribed training programmes to maximise the fitness development.

Keywords

Football; Female football; External workload; Heart rate; Intensity.

INTRODUCTION

Football is the world's most popular sport, practiced across the world.[1] The sports universal appeal is reflected by 260 million, males, females, and children, of all abilities, who participate globally, which corresponds for more than 29 million female participants.[2] Therefore, through obtaining a deeper level of understanding, coaches and players can benefit in terms of their ability to present improved information to modify tactics and training approaches.[3] With female football extensively increasing in stature, the performance expectation has further risen with an increased need for specific scientific research to improve performance[4]. From a physical outlook, football is an intermittent sport[3,5] that requires a well-developed level of conditioning and physical fitness to be played successfully.[6] Throughout the duration of a match, the completed amount of external work completed is characterised by the total distance covered by each player.[7] Nonetheless, given its inability to account for the utility movements and their complete energy costs, total distance alone is not considered to be a valid measure of overall match performance. Rather, the combination of total distance completed, alongside the measurement of heart rate throughout a football match could thus provide a more representative figure.[8,9]

Physical Demands in Football

Physical demands within football have increased across the last decade[3] with all players now participating within defensive and offensive phases; this has created multifunctional footballers, usable within multiple positions.[10] Physical individual variables have been observed within playing positions in all competitive levels of football.[11,12] Numerous studies have compared playing position, presenting a clear link between playing position and physical capacity both aerobically and anaerobically.[13] Being an intermittent sport,[3] the aerobic system is heavily taxed with peak heart rates of 85% HR_{max} and 98% HR_{max}.[10] However, oxygen kinetics undergo changes throughout a football match due to the 150-250 anaerobic short intense bouts performed, indicating a high anaerobic energy turnover.[14,15] The benefits of efficient oxygen kinetics to subsequently benefit footballer's performance due to delaying fatigue and improving recovery, due to the characteristics of football, players have to attain physical qualities including high-levels of aerobic and anaerobic endurance.[14,16] However, Hoff and Helgerud[17] stated that football players do not excel in one single physical component.[16,14] Shalfawi et al[18] affirms that the ability to sustain aerobic and anaerobic endurance further to strength, power and agility for the match, particularly in the second half, are vital to aid physical performance and determine the match outcome.

Positional Variations in External Workload

Studies show the differences in external workload throughout a match.[19]The energy expenditure in performance is directly linked to the mechanical external work output. Conflicting research debates the total distance travelled throughout a match; the concluded distance players cover is 8-12 km, with distances at elite levels reaching 14 km.[20,16] Collective studies, conclude midfielders performing the largest total distance in comparison to other playing positions.[3,10] External midfielders previously recorded distances covering 11990+776 m whilst central midfielders recorded distances of 12027+625 m throughout the duration of a 90-minute match.[14] As a result, centre backs (10627+893 m), external defenders (11410+708 m) and forwards (11254+894 m) display significantly lower overall distances covered.[14] Whereas, external defenders (402+165 m), external midfielders (446+161 m) and forwards (404+140 m) have presented a noticeable difference in total sprinting distance during the duration of a game.[19,14] Central midfielders only recorded total sprinting distances of 248±116 m with centre backs presenting an even lower total sprinting distance (215±100 m).[14] The study by Di Salvo et al[21]supports centre backs low overall distances covered both anaerobically and aerobically resulting in their lower physical capacity and important tactical role.

Midfielders, through covering the largest distances, are unable to work at high intensities and therefore sprint for the same duration as other positions. Covering a larger distance results in working at lower intensities with less opportunity for rest due to midfielder's HR rarely falling below 65% of HR_{max}.[14] Therefore, the working muscles have a continuous demand for oxygen prohibiting anaerobic, high intensity sprinting. External defenders and forwards have further rest opportunities, allowing higher intensities to be met on numerous occasions, thus resulting in larger total sprinting distances.

Positional Variables Affecting External Workload

Total external work completed throughout a game has been found to vary according to a variety of factors which dictate work rate profiles and energy expenditure.[14] Firstly, a player's $V0_{2max}$ can influence the distance performed; a higher physical capacity displays a positive correlation to enable further distance to be completed due to positional and tactical roles.[14] The variation between $V0_{2max}$ and positions influences the ability to cover greater distances at higher intensities; this is further reflected through the increased $V0_{2max}$ values consistently obtained by midfielders, alongside overall largest distances travelled.[14] Secondary factors affecting external workload include the style of play and team formation.[22,20] The evolution concerning style of play within professional football has been suggested by Di Mascio and Bradley,[14] whom produced conclusions which demonstrate an increased distance covered by contemporary English Premier League players (11 km) compared to those in the original First Division (8.2 km) observed by Reilly and Thomas.[23] The increase in 2.8 km supports the physical demands of football increasing with every position involved in defensive and offensive phases across a match.[3,10] Tierney et al[22] stated that there are noticeable differences in the positional demands across a series of formations. Jozak et al[24] claimed that midfielders will always cover the largest total distance in any formation, due to being the direct link between the defensive and offensive part of the whole team.

Heart Rate of Footballers

Heart rate (HR) is a leading tool guiding the intensity level of exercise and determining physical demands.[9,25] The intensity level is expressed as a percentage of maximal heart rate (HR_{max}) due to the large variations that occur throughout 90 minutes within a match. Changes to the modern game[3] has led researchers into developing specific aerobic conditioning concepts for players.[26] Hoff et al-[27]stated that pure running is suitable for players to reach maximum oxygen consumption. However, simply running is not suitable for the development of football specific aerobic capacity, which is more dependent upon aerobic peripheral, rather than central adaptation.[26,28] Within football, it is documented that the maximum benefits are achieved when the conditioning stimuli coincide with specific competitive demands.[26,29]

Heart Rate Intensity in Football

In football, athletes perform different types of physical movements ranging at a series of intensities.[1,8] Santos et al1 claimed that 80-90% of football spent within a low to moderate intensity zone with 10-20% spent completing high intensity activities. These findings do not match previous research by Jozaket al[24] whom presented 30% of overall football activities to be spent at a high intensity. In total, the average myocardium reaction throughout the duration of a 90-minute match is 80-90% of the HR_{max}.[20,30]Coelho et al[30] compared player positions based on intensity within football matches. The researchers concluded that midfielders spent the majority of a 90-minute football match at 85-90% HR_{max}, thus suggesting higher aerobic requirements then defenders and forwards. As a result, Coelho et al[30] suggested a higher requirement of aerobic activities within midfielders physical training to assist with recovery and consequently, their performance.

Fatigue of Footballers

Fatigue has become a high profile topic in intermittent team sports.[31] Waldron and Highton[31] discussed the likelihood that performers whom inversely have an increase in overall work performed, must reflect recovery either partially or fully, overall displaying temporary fatigue. The phrase refers to a period of reduced intensity, which occurs directly after the most intense period which can occur through possession or the match score.[31] Therefore, if players are in possession of the ball, their intensity of play is reduced and external workload reduced, this period of recovery overcomes temporary fatigue. Acute fatigue, which is seen within footballers, occurs as a result of both peripheral and central factors.[31] The immediate peripheral assumption to fatigue isassumed to be due to blood lactate accumulation with a reduction in pH.[31] Waldron and Highton[31] report blood lactate concentrations samples during and after football matches to vary between 7-9 mmo1^{-1}. The findings reveal that team sports players tolerate some degree of lactate accumulation; however, blood lactate accumulations do not appear to increase across the course of the matches.[31] Furthermore, whilst a decrease in pH has been reported after the most intense period within a match, a poor correlation has been connected to decrements in sprinting performance.[31] Overall, the evidence therefore concludes that other factors must contribute towards the reduction in work within football matches and other intermittent sports.

Football matches last 90-minutes, indicating that muscle glycogen is the primary source for ATP synthesis; however, glycogen stores are limited and depleted quickly.[32] Kenney et al[32] stated that since the muscle biopsy technique was introduced, studies show a clear correlation between muscle glycogen depletion and fatigue during prolonged activity. Football is an intermittent sport[3] with over 1000 high intensity actions,[10,20] therefore the working muscles constantly rely on a supply of glycogen to meet high energy demands.[32] As the match prolongs, the constant supply of glycogen slows down causing the muscles to fatigue.[32] This study aimed to: (i) To investigate which position completes the most external work across the varying heart rate intensities, (ii) To compare differences in external workload (distance travelled) completed by each position and their average heart rate intensity and, (iii) Compare the average heart rate intensity of female footballers per 45 minute half of a football match to investigate fatigue

METHODS

Participants and Recruitment

A sample of n=24 amateur female football players (mean±SD; age: 20.7±4.0 years; stretched stature: 165.6±5.8 cm; body mass: 58.1±4.7 kg) were recruited from an amateur football club within the South West of England during the 2016/2017 competitive season (Table 1). Recruited participants were outfield playing positions including defenders (n=8), midfielders (n=8) and forwards (n=8) and possessed at least 5 years of playing and training footballing experience. All participants were over 18 years of age, free from disease, illness or injury. They all completed a Physical Activity Readiness Questionnaire (PAR-Q) before inclusion[33] and provided written informed consent, and understood their right to withdraw. To minimise risk, ethical approval was sought from the University of Gloucestershire Faculty Research Ethics Committee.

Table 1. *General summary ($\bar{x} \pm s$) characteristics for n=24 amateur female football players according to playing position (defenders, midfielders and forwards)*

Variables	Defenders (n=8) $\bar{x} \pm s$	Midfielders (n=8) $\bar{x} \pm s$	Midfielders (n=8) $\bar{x} \pm s$
Age (years)	22.4±5.5	20.9±3.5	20.7±2.1
Stretched Stature (cm)	164.6±2.2	168.3±7.4	163.8±6.1
Body Mass (kg)	59.1±3.7	59.1±3.7	59.1±3.7

Procedures

All participants followed the same protocols leading up to each test to ensure consistency. In the 24 hour period prior to testing participants did not partake in any vigorous exercise and refrain refrain from consuming any caffeine or alcohol.[34] Furthermore, participants arrived hydrated and having not consume large quantities of food within a 2 hour prior to testing. Body Mass was measured in the morning with electronic digital weighing scales and to the nearest 0.1 kg. Stretched stature was also measured in the morning using a Harpenden Stadiometer to the nearest 0.1 cm. After measurements were taken, the mean value was determined for subsequent data analysis. The Yo-Yo IR Level 1 protocol commenced whilst all players entered the middle of the competitive season to determine the maximal HR values for each participant. The week following, the SAFT^{90} procedure was completed.[35] The training load and amount of match play performed for each participant was standardised to the competitive season.

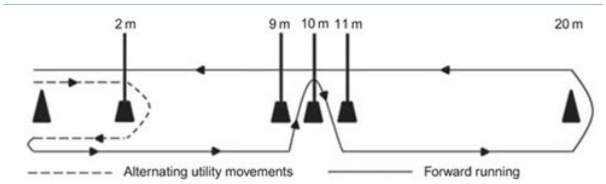
Experimental Session 1

(Yo-Yo Level 1 Intermittent Recovery Test): The Yo-Yo IR Level 1 test was performed on artificial turf in running lanes having a width of 2 m and a length of 20 m.[36,37] Prior to the test, the participants performed a warm up prescribed by Barrett et al[38] and Marshall et al[39] an identical warm up was used prior to the completion of the SAFT^{90}. Procedures suggested by Krustrupet al[40] and Castagna et al[41] for the Yo-Yo IR Level 1 were followed, with runs at a progressive speed, controlled by audio bleeps from a pre-recorded tape.[36] After each bout of running, the players had a 10s rest period.[36] The test result was recorded upon the point when a participant has failed twice to reach to finish line within the allocated time.[36]

Experimental Session 2

(Soccer-Specific Aerobic Field Test (SAFT^{90})): The SAFT^{90}design uses an agility based course whereby players navigate around the 20 m course in an intermittent fashion through stranding (0 km/h), walking (~5.5 km/h), jogging (~10.7 km/h), striding (~15 km/h) or sprinting (maximal effort).[39,42,43,39] The course is based around a shuttle run with the incorporation of 4 positioned poles in which the participants must navigate around (Figure 1).[38,42,43] Altogether, the course provides the participants with 1332 changes in direction and 1269 changes in speed, eliciting internal loads similar to those reported from match-play.[39,38,42,43]

Figure 1. *A diagrammic representation of the SAFT^{90} football match-play course*



Prior to the completion of the test, the participants performed a football specific warm up prescribed by Barrett et al[38] and Marshall et al.[39] The first 8 exercises proposed by Marshall et al[39] involved light jogging further to side-stepping with the inclusion of simple plyometric movements. Dynamic movements followed with each sequence performed twice over a 20 m distance.[39] Final exercises involved sprint-based agility movements before undertaking the SAFT^{90}.[39]

Data Collection Session

Heart Rate: Heart rates were monitored throughout the Yo-Yo IR Level 1 and SAFT^{90} protocols using a HR monitoring system (Polar Team 2 System, Kempele, Finland).[35] Furthermore, the data collected through the completion of the Yo-Yo IR Level 1 quantified the overall HR intensity zones. The intensity of the match was reported as the percentage of time spent in the five HR zones prescribed by Coelho et al[30]. Each zone was identified as a different percentage of HR_{max} zone 1 equates to <70% HR_{max}, zone 2, 70-85% HR_{max}; zone 3, 85-90 HR_{max}; zone 4, 90-95% HR_{max}, with zone 5, 95-100% HR_{max}.[30] Heart rates for each participant were recorded every second of each protocol and quantified to produce data for each minute throughout each 45 minute half and across the 90-minute duration with each position being investigated. The amount of time, alongside the percentage of time spent in each zone was reported in relation to the amount of external work completed for each position. Additionally, differences in HR recordings between positions and across the duration of the protocol (per 45 minute half) was measured, to investigate fatigue.

External Workload*:* Throughout both protocols, in order to obtain overall external workloads, the participants were videoed replicating protocols previously implemented by De Ste Croix et al.[43] The footage attained was then interpreted based on the standardised 20 m guidelines.

Statistical Analysis

Raw data sets were analysed using Microsoft Excel, 2016. Descriptive statistics, including means and standard deviations, were calculation for each measure including, external workload and HR intensities across each 45 minute half. Furthermore, percentage measurements for each position, based on each HR intensity, were calculated. In order to determine the following situations: a) comparison of intensity between the different halves of the match (first half *vs.* second half); b) comparison of each position across the intensity zones; c) comparison of each positions external workload; d) time spent at each intensity across each 45 minute half; a one-way analysis of variance (ANOVA) was applied. The level of significance for statistical testing was set at alpha level $p<0.05$.

RESULTS

On average, the overall external workload for all positions, during the SAFT^{90}, was (mean±SD) 10913.7±1076.7 m. Across the 90-minutes, defenders recorded an external workload of 10020.4±1086.6

Table 2. *Total external workload performed during SAFT^{90} for each position (p) including defenders (d), midfields (m) and forwards (f).*

P	1st Half (m)		2nd Half (m)		Full Game (m)	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
D	5774.6±783.0	4969-6987	4245.8±856.3	3263-5659	10020.4±1086.6	8562-11984
M	6325.3±645.4	5236-6984	5456.6±635.3	4362-6549	11781.9±324.7	11236-12142
F	6325.3±645.4	5002-6954	4935.1±633.2	4071-5762	10938.9±865.2	9412-11985
ALL	6034.5±727.8	4969-6987	4879.2±851.3	3263-6549	10913.7±1076.7	8562-12142

Table 3. *Mean heart rate (HR) during SAFT^{90} for each position (p) including defenders (d), midfields (m) and forwards (f).*

P	1st Half (bpm^{-1})		2nd Half (bpm^{-1})		Full Game HR (bpm^{-1})	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
D	140.4±6.7	130.0-148.0	148.1±9.4	136.0-160.0	144.3±7.4	136.0-154.0
M	181.0±13.3	146.0-183.0	170.0±9.2	157.0-180.0	168.8±10.8	152.0-181.5
F	170.1±7.5	146.0-183.0	170.4±9.4	154.0-183.0	170.3±7.4	159.0-184.0
ALL	159.4±16.6	130.0-185.0	162.8±13.9	136.0-183.0	161.1±14.7	136.0-184.0

m, whilst forwards recorded a distance of 10938.9±865.2 m, and midfielders an external workload of 11781.9±324.7 m. Therefore, across the 90-minute SAFT^{90}, midfielders overall performed the largest proportion of external work. Across each 45 minute halves of the SAFT^{90}, midfielders consistently recorded the highest external workload. Across the opening 45 minutes, midfielders recorded distances of 6325.3±645.4 m, with forwards documenting distances of 6003.8±32.2 m and defenders, the lowest of the three outfield positions, 5774.6±783.0 m. This trend continued into the second half of the protocol, with midfielders maintaining the highest external workload (5456.6±635.3 m), with forwards distances of 4935.1±633.2 m and repeatedly, defenders the lowest of the three positions (4245.8±856.3 m). Furthermore, between the two separate halves, all players demonstrated a decreased external workload in the second half (6034.5±727.8 m) in comparison with the first 45 minutes completed (4879.2±851.3 m). A one-way ANOVA showed that the effect of position within female football on the external workload performed during a 90-minute SAFT^{90} was significant (F(df:23)=9.156; p<0.05). However, across the two separate 45 minute halves, significance results differed. Within the first half, the effect of position on the external workload performed was not significant, whereas, the second half showed there to be a significant difference between the playing positions and overall external workload completed(F(df:23)=5.758; p< 0.05).

Based on the results illustrated in Table 1, defenders present the lowest average HR (144.3±7.4 bpm^{-1} in comparison with forwards (170.3±7.4 bpm^{-1} and midfielders (168.8±10.8 bpm^{-1}) across the 90-minutes of recorded data. This trend is further present between the two 45 minute halves. Across the first 45 minutes, defenders recorded an average HR of 140.4±6.7 bpm^{-1} significantly lower than midfielders (181.0±13.3 bpm^{-1} and forwards (170.1 ±7.5 bpm^{-1}. In the second half, forwards displayed the highest average HR of 170.4±9.4 bpm^{-1} in comparison with midfielders (170.0±9.2 bpm^{-1}) and forwards (148.1±9.4 bpm^{-1}). Across the two halves of the 90 minutes, defenders and forwards each presented average HR data showing an increase, from the first half to the second, midfielders however, demonstrated a decreased. The average HR recorded for all positions across the SAFT^{90} was 161.1±14.7 bpm^{-1} as shown in Table 2, with the average intensity during the protocol for all defenders, midfielder and forward represented 81% HR_{max}.

Figure 2 and Figure 3 demonstrate that midfielders and defenders continually displayed lower average heart rates than forwards per 15-minute bout of the SAFT^{90}. Within the opening 15 minute bout (Figure 2), all three positions present an increase in HR, following into the second bout (15-30 minutes), only at the 23rd minute did each positions HR plateau. Figure 1 illustrates average heart rates from midfielders and forwards maintaining 150-200 bpm^{-1}, however defenders continually work between 100-150 bpm^{-1}. Defenders further display periods of increased and decreased heart rates with decreases falling in both the 35th-37th minute and 41st-43rd minute. Towards the end of the opening half of the SAFT^{90}, both midfielders and defenders show a decrease in average HR.

Across the entire bout, defenders displayed much lower heart rates showing a range between 135-160 bpm^{-1} in comparison with midfielders at 160-180 bpm^{-1} and forwards at 170-190 bpm^{-1}. The final bout displayed both the midfielders and forwards HR decreasing in comparison with the previous 15-minutes (Figure 3). Similarly, defenders showed periods an increased HR of 160 bpm^{-1} at 77 minutes and 165 bpm^{-1} at 85 minutes, with periods of a decreased HR of 140 bpm^{-1} at 80 minutes and then 87 minutes. However, the final 3 minutes of the entire protocol presents all three positions average heart rates decreasing.

A one way ANOVA showed the effect of position, within female football, on the average HR during a 90 minute SAFT^{90} was significant (F(df:23)=22.317; p<0.05). Furthermore, results showed a significant difference between defenders, mid-

Figure 2. *Average HR for defenders, midfielders and forwards per 15-minute bout of the first 45 minute half of the SAFT[90] including 1-15 minutes, 15-30 minutes and 30-45 minutes*

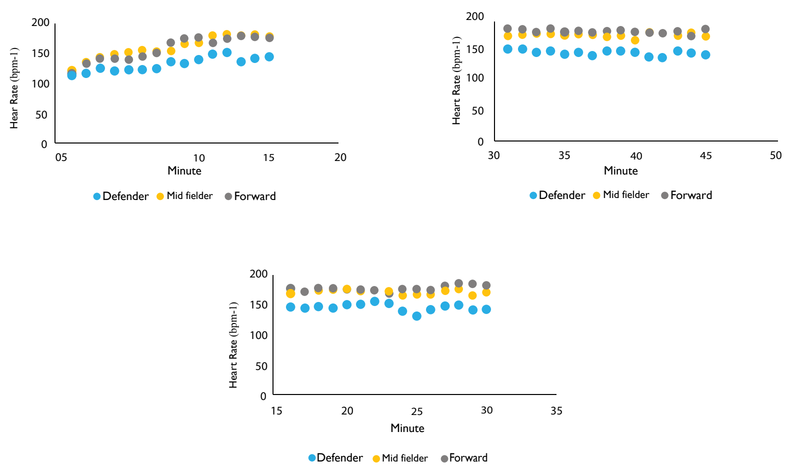


Figure 3. *Average HR for defenders, midfielders and forwards per 15 minute bout of the second 45 minute half of the SAFT[90] including 45-60 minutes, 60-75 minutes and 75-90 minutes*

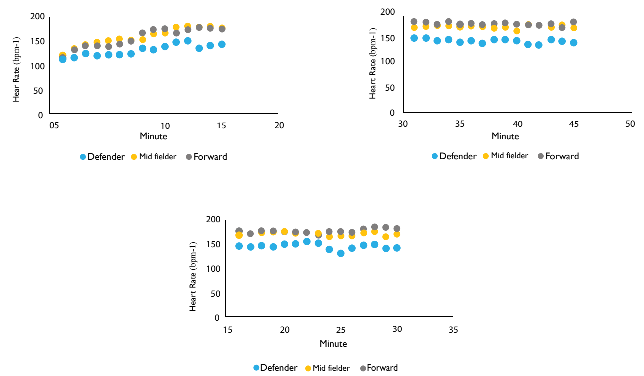
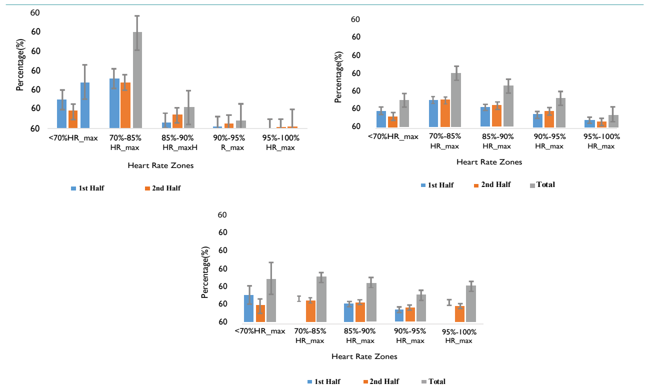


Figure 4. *Percentage of time defenders, midfielders and forwards spent within zone 1, <70% HRmax; zone 2, 70 – 85% HRmax; zone 3, 85-90 HR_{max}; zone 4, 90-95% HRmax and zone 5, 95-100% HRmaxfor first 45 - minute half; second 45 minute half and full 90 minutes of the SAFT[90]*



fielders and forwards average HR across both the first 45 minute half (F(df:23)=23.405; p<0.05) and second 45 minute half (F(df:23)=14.925; p<0.05).

Heart Rate Intensities

Across the total SAFT[90], the average intensity for all positions represents 81% HR_{max}, which in line with the investigation means within zone 2 (70-85% HR_{max}). Within the first half, the average intensity for all positions represents 80% HR_{max}; however, in the second half, average intensity increased to 82% HR_{max} but was maintained in zone 2. Through the completion of a one way ANOVA, significance results showed position, to have an effect on the level of intensity and time spent at each intensity. Across theSAFT[90], there was a significant difference between playing position and the duration spent working within zone 1, <70% HR_{max}(F(df:23)=5.271; p<0.05); zone 2 between 70-85% HR_{max}(F(df:23)=5.965; p<0.05) and zone 4 at 90-95% HR_{max}(F(df:23)=4.433; p<0.05). However, across zone 3 between 85-90% HR_{max} and zone 5 at 95-100% HR_{max}, no significant difference was found between each position and the duration spent working at each intensity. Within the opening half, defenders average intensity was 73% HR_{max}, working within zone 2 (70-85% HR_{max}). However, midfielders and forwards average intensity represented that of zone 3 (85-90% HR_{max}), with midfielder's average intensity at 88% HR_{max} and forwards 86% HR_{max}. In comparison with the second half, forwards display no change in average heart rate intensity. Midfielders however moved into zone 2 (70-85% HR_{max}) at 83% HR_{max}. Defenders nonetheless display an increase in average heart rate intensity to 78% HR_{max}; however, still maintained working within zone 2 (70-85% HR_{max}).

Across the 90-minutes (Figure 3), all three positions spent time in each HR zone, from zone 1 to zone 5. All positions each spent the largest percentage of the SAFT[90] in zone 2(70-85% HR_{max}). Specifically, within zone 1 (<70% HR_{max}), defenders spent the larger percentage of time with forwards the least, whereas, at the highest intensity, in zone 5 (95-100% HR_{max}), forwards spent the larger percentage of time with defender's the least. Midfielders specifically spent the largest percentage of the 90-minutes within zone 3 (85-90% HR_{max}) and zone 4 (90 -95% HR_{max}) in comparison with the further outfield positions.

Figure 3 display differences between the HR intensities between the two 45-minute halves of the $SAFT^{90}$. Within the first half, all three positions worked across each HR zone; however, in the second half, defenders never worked with in zone 5 (95-100% HR_{max}). Similarly, between the first half and second half, all three positions spent the largest percentage of the game at 70-85% HR_{max} in zone 2. Specifically, across both halves of the protocol, midfielder's largest duration of time was spent within zone 2 and 3 working in total across 70-90% HR_{max} whereas defender's largest percentage of time was spent within zone 1 and 2. Forwards in comparison spent the smallest percentage of time within zone 1; however, increasingly more from zones 2 to zone 5 with HR intensities varying from 70-100% HR_{max}.

Significance results of a completed one-way ANOVA showed position has an effect on the level of intensity and time spent at each intensity. Across the first 45-minute half of the $SAFT^{90}$, there was a significant difference between playing position and the duration spent working within zone 1 <70% HR_{max}, (F(df:23)=6.379; p<0.05); zone 2 between 70-85% HR_{max}(F(df:23)=5.076; p<0.05); zone 3 (85-90% HR_{max}) (F(df:23)=4.997; p<0.05) and zone 4 (90-95% HR_{max}) (F(df:23)=4.635; p<0.05). However, no significant difference was found between position and duration working at the intensity of zone 5 (95-100% HR_{max}). Across the second 45-minute half, no significant difference was found between each position, for the duration of time spent within, zone 1 (<70% HR_{max}), zone 3 (85-90% HR_{max}) further to zone 4 (90-95% HR_{max}) and zone 5 (95-100% HR_{max}). Within the second 45-minutes, significant differences were found between all three positions and the duration of time spent within zone 2 (70-85% HR_{max}), (F(df:23)=4.580; p<0.05).

CONCLUSION

External Workload

In total, for all three positions, the total external workload completed across 90-minutes was 10913.7±1076.7 m with a range of 8562-12142 m. The findings correspond to previous research showing the average distance players cover during a match is 8-12 km.[16,7,20,] Statistical analysis across the 90-minutes concluded a sinificant difference between the workloads completed between the three positions. On average, the largest external workload completed was by midfielders (11781.9±324.7 m) followed by forwards with defenders covering the smallest distance covered (10020.4±1086.6 m). Other studies have also found midfielders to cover the greatest external workload.[3,10,44] The completed distance for midfielders (11781.9±324.7 m) further corresponds to that of previous studies within the range of 10-12 km.[10,44]

The protocol removes oppositional effects and tactics, resulting in the physiological and mechanical demands displayed during football match-play being observed; therefore, it can be concluded that the greater distances were not due to tactics and styles of play.[34,42] Midfielders however, to have developed higher physical capacities or VO_{2max} levels due to their overall roles within match play, through involvement in both attacking and defensive phases of play in comparison with their counterparts, who rarely cross or retreat past the half way line.[45] Therefore, with an increased physical capacity, more external work is able to be completed. However, with regards to total external workload, other variables further to VO_{2max} may have influenced the results. These variables include changes in the intensity of activity as well as motivation.[8] Between the three positions, defenders covered the lowest external workload (10020.4±1086.6 m). Indeed, several studies have previously found defenders to obtain, in general, lower fitness levels, resulting in lower external loads performed in comparison with midfielders and forwards.[20,44] Research by Di Salvo et al[21] supports defender's low overall distances covered both anaerobically and aerobically as the result of their lower physical capacity and tactical role to complete small bouts of movement in winning duels and aerial challenges.[24]

Heart Rate

Considering the load intensity from a physiological point of view, average HR results across the 90-minute $SAFT^{90}$ for all players was 161±14.7 bpm^{-1} corresponding to 81±7.4% HR_{max}. This matched heart rates previously obtained within research by Andersson et al[44] who found the average HR of female footballers within domesticated matches to correspond to 162±6 bpm^{-1} or 85±3% of HR_{max}. However, the participants of the study were international female players from Sweden and Denmark, playing professionally, in comparison with amateur footballers.

The football simulated match intensity found in the present study did not differ markedly from those reported in other investigations. Coelho et al[30] evaluation of 26 footballers, during a championship game, reported an overall intensity of 84% HR_{max}. Furthermore, Mohr et al[46] reported an intensity of 85% HR_{max} during a friendly match of the 4th division, whilst O'Connor[47] evaluated HR during two women's and men's soccer games finding an intensity of 85% HR_{max}. However, both studies evaluated friendly matches rather than a simulated football match. Intensity observed in the present study further matches than that obtained by Reilly and Keane,[48] who evaluated senior soccer players in a specific simulated test with the mean intensity presented at 80% HR_{max}. Although maximum effort tests are suitable for the determination of HR_{max}, a previous study by Antonacci et al[49] showed that HR_{max} is lower in simulated tests, than during official matches.

Heart Rate Intensities

Focusing on the total 90 minute $SAFT^{90}$, the average intensity for all positions was 81% HR_{max} which in line with the investigation means within zone 2 (70-85% HR_{max}). The data, as a result, corresponds with other studies findings.[30,44,46] Throughout the first half, the average intensity for all positions was 80% HR_{max}; however, within the second half the average intensity increased to 82% HR_{max}. This meant across both 45-minute halves working within zone 2 (70-85% HR_{max}). However, the results contradict the research conducted by Coelho et al[30] whom observed a decrease in game intensity from the first to second half of a championship football game. Mortimer et al[50] stated that a reduction in game intensity occurs during the second half of a football match, due to the role of fatigue as a result of the progressive utilisation of glycogen, which decreases during the second half. With focus on each of the position, forwards average HR did not differ between either of the halves of football and maintained 86% within zone 3 (85-90% HR_{max}), whereas defenders rose from the first half (73% HR_{max}) to the second half (78% HR_{max}). Midfielders average HR from the first half (88% HR_{max}) in comparison to the second half (83% HR_{max}) was the only decrease supporting previous research. A similar decline had been reported in other studies.[30,46] The lack of significant difference between the two halves of the game for forwards is however supported by Vencurik et al[51] who witnessed no changes between certain positions physiological demands across the two halves of a female basketball match.

Across the 90-minutes, results displayed differences between each of the HR intensity zones, however significant differences were only found between the duration each position spent within zone 1, zone 2 and zone 4. Nonetheless, across the 90-minutes, each position spent time within each zone. All three positions each spent the largest percentage of the $SAFT^{90}$ within zone 2 (70-85% HR_{max}) in comparison with the other intensity zones. Defenders spent the largest percentage of time within zone 1, with forwards the least, whereas, at the high intensities, in zone 5, forwards spent the larger percentage of time with defenders the least. This result demonstrates the importance of HIR for forwards and LIT for defenders. Di Mascio and Bradley,[14] analysed the evolution of football describing forwards movements to focus around high intensities and short-duration efforts, with defenders maintaining a low intensity with minimal HIR, therefore, the current study backs up that of previous research.[10,4]

The results however, contradict the research by Jozak et al[24] who studied 600 players during the world cup finals; results showed defenders and forwards to have completed the most LIR due to the positions having the least contact with the ball. However, the comparison must be taken with caution due to the sample using male international athletes during competitive matches, resulting in formations and tactics potentially interfering with play.[22,20] A further finding includes midfielders specifically spending the largest percentage of the 90-minutes within zone 3 and zone 4. Research by Coelho et al[30] and Goncalves et al[25] reported the similar findings. Furthermore, Orendurff et al[52] investigated differences in positions during a game using a step rate as an intensity parameter; the results obtained were similar to those observed in both the current study but further the investigation by Coelho et al.[30] Midfielders presented a similar game pattern characterised by few maximum intensity bouts (step rate=7) and short recovery bouts of moderately high intensity (step rate=4), thus in agreement with studies showing a higher aerobic capacity of midfielders.[30,45]

First Half *Versus* Second Half Fatigue

It is generally accepted that physical performance declines during a match because of increased fatigue towards the end of a game.[36,42] Within the current study, first half differences in comparison second half suggest all positions to experience fatigue. External workload decreased for all positions by 11% with a first half overall workload of 6034.5±727.8 m in comparison to a second half workload of 4879.2±851.3 m. Furthermore, defenders, midfielders and forwards individual workloads completed each decreased. The findings further support numerous research that indicates that the fatigue induced by the physical activity completed during the fi rst half is related to the physical activity completed during the second.[4,19,44]

Within the first half, all three positions worked across each HR zone; however, in the second half defenders never worked with in zone 5 displaying a slowly declining intensity. Furthermore, the percentage of time defenders spent within zone 1 and zone 2 increase in the second half. Additionally, midfielder's intensity decreased at the highest intensity (95-100% HR_{max}) by 2%, further to forwards by 4%. Moreover, forwards time within zone 2 and zone 3 and zone 4 increased within the second half in comparison with the first. Specifically, forwards duration of time spent in zone 3 increased by 2% and in zone 4, by 3%. Martinez-Lagunas et al[4] stated that the amount of HIR completed in the second half, compared to the first half of match-play, decreases due to temporary and permanent forms of fatigue. Since football game intensity and fatigue is influenced by the opponent and tactical preferences of the coach, the data should be considered carefully due to using a $SAFT^{90}$. Nonetheless, Jones et al[42] stated that the fatigue induced by the $SAFT^{90}$ protocol is representative of the responses associated with actual football match-play.[53]

In summary, overall external distance during a $SAFT^{90}$ is similar to that of competitive match-play. The results indicated that all positions workloads externally are different, with midfielders achieving the highest overall distance, in comparison with forwards and defenders, who completed the least. Defenders spent a higher percentage of the protocol within the lowest intensity zones with forwards rarely performing below zone 2 (70-85% HR_{max}) resulting in forwards spending the largest percentage of the game at the highest intensities. This data should be included in specific training programmes addressing the tactical positions of players. In the case of forwards, the objective is to increase performance at short-durations and at the highest intensities, since their main focus is to move at pace to create space to receive the ball or break through oppositions defensive lines. Midfielders are the players who spent the most time between zone 2 (70-85% HR_{max}), zone 3 (85-90% HR_{max}) and zone 4 (90-95% HR_{max}). In addition, across both halves and the total 90-minutes, they spent a higher percentage of time in zone 4 (90-95% HR_{max}) than defenders and forwards, suggesting higher aerobic requirements of these players. This higher requirement of aerobic activities should be included in the physical training of midfielders to improve their recovery and consequently their performance.

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Effects of Different Types of Active Recoveries after Supramaximal Exercise on Exercise-Induced Stress and Subsequent Anaerobic Power Testing

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ABSTRACT

Aim: This study aimed to elucidate the efficacy of active recovery (AR) after supramaximal exercise in six-healthy adult male university students who habitually exercised.

Methods: Prior to this test, the participants underwent the normal walking (W) and Nordic walking (NW) tests to determine their physical strength and intensity levels that will be utilized during their supramaximal exercise test and AR sessions. After 3 min of warm-up exercise, the participants started the main exercise at an intensity of 120 %VO_{2max}. After completing the main exercise, the participants immediately moved to a treadmill and performed 20 min of AR at a speed equivalent to 4 METs, calculated based on the walking tests. To eliminate the order effect of W and NW, the participants were randomly assigned one of the tests. The main exercise I (Ex I) consisted of the same VO_2, heart rate (HR), and total work load. After completing the Ex I, the participants immediately performed AR.

Results: No differences were observed between the two groups in terms of VO_{2max}, HR or rate of perceived exertion (RPE) ratings during AR because all the values gradually declined immediately after the exercise. Compared with the W group, the lactic acid (La) level of the NW group during AR was lower than that immediately after the exercise (p< 0.05). Because the participants who performed the main exercise II (Ex II) had the same exercise performance as those who performed the Ex I, no significant differences were observed between the two groups in terms of the exercise parameters.

Conclusions: This was likely explained by the fact that La produced by the fast fibers of the agonist muscles circulates within the tissues or throughout the entire body and is used by the lactobacillus shuttle in the fibers of the myocardium and slow muscles as an energy substrate during oxidation.

Keywords: Active recovery; Repeated supramaximal exercise; 8-OHdG; Nordic walking.

INTRODUCTION

Physical exhaustion is experienced after vigorous exercise due to a variety of factors, including the production of multiple exercise-induced substances such as blood lactic accumulation (La) in the blood, salivary amylase[1,2] which is a marker of increased parasympathetic activity, and 8-Oxo-2'-deoxyguanosine (8-OHdG),[3] which is a marker of DNA oxidative damage.

In individuals who are engaged in sporting events, such as track and field and swimming that involve multiple repetitive actions over a single day, physical recovery from fatigue before the next sporting event is an important issue. The types of recovery can be broadly classified into passive recovery, which is a cooling down period of rest, and active recovery (AR), which is achieved exercise. In general, the optimal type of AR is a low-intensity (30-40% VO_{2max}) aerobic exercise.[4,5]

La is associated with fatigue because higher levels of La in the blood cause a decline in pH. Specifically, increased production of hydrogen ions interferes with ATP-synthesis in skeletal muscles, which in turn makes it difficult to induce muscle contraction. Contrastingly, La is sometimes also considered as a source of energy. Although La is produced from the unoxidized pyruvic acid during ATP production *via* anaerobic metabolism by type IIb and other types of fast muscle fibers, particularly those with abundant mitochondria (e.g. myocardial cells and type I fibers), it is used as an energy source during aerobic processes.[6,7] Thus, the use of different types of exercises that utilize the cardiac muscle and type I fibers (thereby utilizing La) are more likely to be effective in AR.

Occasionally, an athlete can collapse after completing an event, such as a cycle sprint or a short-or medium-distance sprint which mainly involves the utilization of leg muscles. When this type of acute passive recovery occurs after supramaximal exercise, the volume of blood returning to the heart from the lower limbs decreases, which causes the loss of consciousness.[8] Abrupt cessation of exercise may lead to hyperventilation,[9] maintenance of La levels,[10] and persistent muscle pain.[11] In cases where athletes are already exhausted after engaging in a sporting event, they may not be able to perform AR exercises. Thus, an easy method for performing AR for athletes must be investigated.

Since 2000, Nordic walking (NW) originating in Finland has gained in popularity as a healthy sports activity by northern Europeans.[12] At a given walking speed, NW involves upper body muscles and induces greater exercise intensity asrising energy consumption compared with normal walking (W).[13-15,17]

The aim of our study was to clarify the effect of active recovery (AR) after supramaximal exercise in which the leg muscles was taken as the protagonist muscles. In this study, the participants performed one of the two different types of AR exercises, wherein they were required to support their body weight. These AR activities were performed after a supramaximal exercise in which the leg muscles were utilized as the protagonist muscles. The intensity of the AR tasks was the same as that of the exercise task. An anaerobic power test (AT) was then implemented, and its effect on the AR task was investigated.

METHODS

Participants

The participants were healthy adult men who habitually exercised (n=6). Their age, height, weight, body fat percentage, and blood pressure (systolic) were as follows [mean±standard deviation (SD)]: 21.8±0.8 years, 174.7±3.7 cm, 74.3±6.7 kg, 12.4%/2.4%, 120.0±8.8 mmHg, respectively (Table 1). All subjects regularly engaged in physical exercise. All participants were familiarized with the experimental procedures, and it was ensured that the attachment of the experimental device to the body did not have any effects on the physiological responses of the participants each exercise protocols. The participants were instructed not to consume large amounts of caffeinated or alcoholic beverages on the day prior to the testing and to get enough sleep on the previous night. They were also instructed to eat breakfast on the day of testing, to stop eating at least 2 h prior to the testing, and to be at rest in the testing room. As high-intensity exercises were involved in this study, the participants underwent a pretest for safety purposes, and those who could reach a VO_{2max} of at least 50 mL/kg/min were selected. All the participants were provided with a complete oral and written explanation of the objective, contents, safety, and ethical considerations of the study, such as data management procedures prior to the start of testing, and informed consent was obtained from them. This study was approved by the institutional review board of Juntendo University Faculty of Health Science and Nursing (Approval No: 24005).

Procedures

Overview: To elucidate the AR effect of NW performed after the main exercise at an intensity of 120% VO_{2max}, the physiological response to a performance test during and after recovery was investigated. The tests consisted of two types and were conducted as pretests at least one week before main exercise: 1) all-out test (stepped exercise load test using a cycle ergometer) and 2) walking test [treadmill walking of either the W or NW type at a speed of 60–120 m/min]. The main tests were conducted under the conditions indicated below. To eliminate the order effect, the participants were randomly assigned to perform one of the tests, and the effect of AR was measured using the cross-over method. In consideration of the carryover effect, at least 1 week was secured during each test.

1) W test: It was performed as an AR activity after the Ex I. After 5 min of seated rest, Ex II was performed, followed by AT, involving three sets of full-speed pedaling for 10 s at 2-min intervals.

2) NW test: It was performed in a similar manner as the W test; however, it was utilized as the AR activity.

Pretest protocol: At least 1-week prior to main test, the participants performed 1) maximal exercise test for measuring the VO_{2max} and 2) Walking (W and NW) test for calculating AR intensity.

Maximal exercise test: The participants performed a maximal ex-

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ercise test on a cycle ergometer to calculate the exercise intensity of the main exercise tasks. The participants entered the testing room 30 min prior to the start of the test. After checking their overall physical condition, height, weight, and blood pressure were measured, and they were then instructed to rest. Blood pressure was measured using a digital sphygmomanometer (TERUMO). HR was measured by placing the electrocardiography (ECG) electrodes at the following locations: the manubrium of the sternum, acromion, and midaxillary line of the fifth rib. The participants remained at rest in a seated position, and an air collection mask was fixed to their faces to measure their respiratory gas concentration and ventilation volume. After measuring their resting metabolism for 5 min, the stepped exercise tolerance test was performed using a cycle ergometer (PowerMax VIII, Combi Wellness Corporation, Tokyo, Japan). After 2 min of pedaling at 90-rpm revolutions and 1.0-kp load, the load was gradually increased at the rate of 0.2 kp/min until the participant was exhausted.[16] The reason why the pedaling exercise employed "90 rpm" rather than the general 60 rpm is because the main exercise is performed with 120% VO_{2max} intensity, which is suitable to be more type II fiber recruitment.[17]

The participant's subjective evaluation of the exercise intensity was recorded using the Borg scale 15 s before increasing the load and speed. The VO_{2max} criteria were as follows: leveling VO_{2max}; achieving maximum HR; and achieving Borg scale score of 20.

Walking (W and NW) tests: Prior to the start of the test, W and NW tests were conducted to calculate the W and NW speeds, respectively, during the AR activity. The AR intensity in this study was set at 4 metabolic equivalents (METs) of the task, and the walking speed at this intensity was calculated using the interpolation method. The oxygen intake of the participants at rest was 4.3±0.9 mL/kg/min, and their VO_{2max} was 54.1±2.6 mL/kg/min, indicating that the intensity of 4 METs ranged from 25.7% to 31.0% of VO_{2max} The maximal exercise test was performed in a similar manner as the above mentioned preparations, except that the resting metabolism was measured. The treadmill inclination was set at 5%. The participants performed the W test for 2 min, followed by the NW test for 2 min. Thus, their walking speed was gradually increased over 4 min, with the walking time increasing from 60 m/min to 120 m/min.[14] The device was set to allow walking speeds of up to 120 m/min in each case. The subjective exercise intensity assessment results of the participants were recorded immediately prior to shifting from the W to NW test and again immediately before the conclusion of the NW test using the OMNI scale.

Main test protocol (Figure 1): The participants performed the same above mentioned preparations. Their respiratory gas and blood La levels were measured while at rest. The position of the cycle ergometer was adjusted as follows: the participants mounted and placed the device, with one foot on the pedal, to adjust the height so that the knee was at maximum extension. Immediately after the resting period, the participants mounted the cycle ergometer and performed 3 min of warm-up at 1.5 kp×60 rpm. The Ex I consisted of 90 s of pedaling at an intensity of 120% VO_{2max}.The load equivalent to 120% VO_{2max} when pedaling was performed at 120 rpm was recalculated from the load (kp)-%VO_{2max} relational expression at the maximal exercise test (Table 1). This high frequency in the Ex I and II assumes the condition that recruitment

Figure1. *Main Exercise (Ex I and Ex II) Protocol*

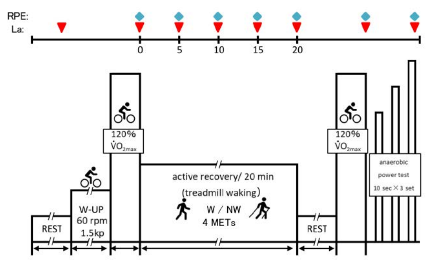

Table 1. *Physical Characteristics and VO_{2max}, HR_{max} and the Main Exercise Load (120% VO_{2max}) obtained in Maximal Exercise Test*

Subject	Age (yrs)	Height (cm)	Weight (kg)	%Fat (%)	Mean of systolic blood pressure (mmhg)	vo_{2max} (ml/min/kg)	HR_{max} bpm	Exercise load 120% VO_{2max}:kp
A	22	175.2	74.8	12.6	121	56.8	179	3.61
B	22	171.5	65.5	9.5	125	55.1	174	3.33
C	21	173.7	77.6	12.5	130	51.7	191	3.65
D	22	179.1	82.2	14.4	122	50.3	177	3.94
E	21	178.6	78.7	15.6	104	56.6	190	3.63
F	23	169.8	66.8	9.7	118	53.9	180	3.20
mean	21.8	174.7	74.3	12.4	120.0	54.1	181.8	3.56
SD	0.8	3.7	6.7	2.4	8.8	2.6	7.0	0.26

maximum oxygen uptake; vo_{2max}

maximum heart rate; HR_{max}.

of type II fibers increases and anaerobic metabolism is promoted.[18] After the completion of this exercise, they immediately moved to the treadmill, where they reproduced the same VO_{2max} as that during the walking test; then, they performed 20 min of AR at a speed equivalent to 4 METs under both conditions. The participants were instructed to walk assuming that they were pressing against the floor with their lower limbs while performing the NW test. The length of the poles used during the NW test was similar to that of the poles used in the pretest (height×0.68), which was in accordance with the International Nordic Walking Association (INWA) guidelines.[12] After AR, the participants remained seated for 5 min and then performed the Ex II with the same intensity as that of Ex I. Then, they immediately performed AT. Their performance results were then compared

Measurements

Physiological parameters: The respiratory gas concentrations were corrected using the concentrations of three types of gases that were measured prior to the exercises (O_2, 15.71%; CO_2, 4.47%; and N_2, 79.81%). The respiratory gas concentration and ventilation volume were measured every 15 s during both the resting and exercise periods using an automatic respiratory gas analyzer aerometer (AE-310s, Minato Medical Science Co. Ltd, Osaka, Japan).

HR was measured using a patient monitoring device (BSM-2401, Nihon Kohden Corp., Tokyo, Japan). ECG waves were continuously recordedand were subjected to A/D conversion (PowerLab 16/30, ADInstruments, Sydney, Australia) at 1 kHz. The data were then entered into a specialized computer software (LabChart 7 Japanese, ADInstruments, Sydney, Australia), and at 30-s intervals in the continuously recorded data, HR (bpm) for each minute was calculated from the number of R-peaks.

La levels were measured using a blood lactate analyzer (Lactate Scout, EKF Diagnostics, Cardiff, UK). When collecting blood samples, the participants' fingertips were disinfected using alcohol and a cotton swab and then completely dried. Next, the fingertip was punctured using a lancet (BD Safety Lancet, BD, Japan). The initial quantity of blood from the puncture was wiped away using Kimwipe™, and 0.5 μl of blood was then collected.

We measured 8-Oxo-2'-deoxyguanosine (8-OHdG) activity, which is an index of exercise-induced stress, in the urine using a urinary oxidative stress marker monitor (ICE-001, TechnoMedica Co., Ltd., Kanagawa, Japan). Prior to the pretest resting period, immediately after the test, approximately 2 mL of urine samples were collected, which were then frozen until analysis.

Localized fatigue in the upper and lower limbs: The participants underwent subjective assessments of localized fatigue of the upper and lower limbs using the visual analog scale (VAS) immediately after the start of AR, at 2 and 5 min, and thereafter at 5-min intervals up to 20-min after the test. A Likert-type scale ranging from not fatigued at all (0 mm) to fatigued (100 mm) was used by the participants who placed a check mark at the appropriate level.

Work and workload: Work was measured by recording the continuous data for power value (WATT) every 0.1 s that was output by the computer receiving the data from the cycle ergometer. To eliminate the effect of the participant's body types when comparing the data, we calculated the value after dividing by the body weight (watt/kg). The total workload over a 90-s interval (kg×m) was calculated by dividing the workload for the 90-s interval calculated at every 0.1 s by 1.02.

Statistical analysis: All the measurement results were presented as the mean±SD. Regarding the normality of the data, we confirmed the results consistent with the Gaussian distribution, and then 2-way ANOVA was applied. In cases where a significant difference was observed, the Bonferroni test was used as a *post-hoc* test. Differences in the mean values of speed and work, maximal AT values, and La after Ex Iand II were analyzed using the paired student *t*-test. The standard of significance was set at <5%. Statistical analysis was performed using Prism6 (GraphPad Software, USA).

RESULTS

Pretest

All-out test: VO_2 and HR increased as the speed and load increased. The participants maximum oxygen intake (VO_{2max}) and maximum HR (HR_{max}) were 54.1±2.6 mL/kg/min and 181.8±7.0 bpm, respectively. The main exercise load calculated using the load and $\%VO_2$ regression formula at 120 rpm was 3.56±0.26 kp (Table 2).

W and NW tests: No significant differences were observed between VO_2 for W and NW at 60 m/min. However, the following VO_2 values were obtained for the tests: 18.7±2.1 and 20.5±3.2 mL/kg/min at 80 m/min (p<0.05); 24.6±3.5 and 26.7±4.1 mL/

Table 2. *Walking speed at 4 METs, expected HR and VO_2 obtained in Walk test*

Subjects	speed (m/ min)		VO_2 (ml/min/kg)	HR (bpm)	
	W	NW		W	NW
A	60.0	57.0	14.2	90.0	92.8
B	91.2	87.6	21.4	108.1	107.6
C	66.7	60.4	15.9	92.2	92.9
D	85.5	79.0	12.6	85.6	88.5
E	69.2	61.9	21.4	109.9	112.7
F	66.0	51.5	16.8	94.4	84.8
mean	73.1	66.2*	17.1	96.7	96.6
SD	12.3	14.0	3.7	10.0	11.1

*p<0.05, compared to W

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kg/min at 100 m/min (p<0.05); and 32.6±3.8 and 36.3±4.3 ml/kg/min at 120 m/min (p<0.05), respectively. These results indicated that the VO_2 values were speed-dependent and were higher for NW than for W (Figure 2a).

No difference was observed between the HRs in W and NW at 60 and 80 m/min. However, the following values for W and NW were obtained: 117.3±11.8 and 123.8±14.1 bpm at 100 m/min ing (p<0.05) and 141.0±12.1 and 150.3±14.7 bpm at 120 m/min (P<0.05), respectively. These results indicated that HR was speed-dependent and tended to be high for NW than for W, which was similar to that observed for VO_2 (Figure 2b).

The walking speeds equivalent to an intensity of 4 METs during AR activity as calculated based on the walking tests are shown in Table 1. The walking speeds for W and NW were 73.1±12.3 and 66.2±14.0 m/min, respectively, indicating that the walking speed for NW was significantly lower than that for W (p<0.01). The anticipated VO_2 and HR when AR was performed at these walking speeds were 17.1±3.7 mL/kg/min (both the groups), 96.7±10.0 bpm (W), and 96.6±11.1 bpm (NW), respectively (Table 2).

Main Exercises

Ex I: The total values calculated from the Ex I were 3761.2±229.6 kg×m for W and 3730.6±249.1 kg×m for NW, indicating that there was no significant difference between them (Figure 3d). The comparison of the power values (WATT/kg) sampled at 0.1-s intervals during Ex I indicated that there was no significant difference between N and NW. However, within 1 s after standing, NW had a significantly lower power value than W (p<0.05; Figure 3a). The investigation of VO_2 (Figure 3c) and HR (Figure 3d) for both the conditions during Ex I indicated that there were no significant differences between the two conditions, suggesting that the same exercise load was applied to both the exercise groups.

AR: Physiological response and subjective assessment of exercise intensity during AR The investigation of VO_2 and HR while at

Figure 2. *Changes of VO_2(a) and HR(b) in Walking Test*

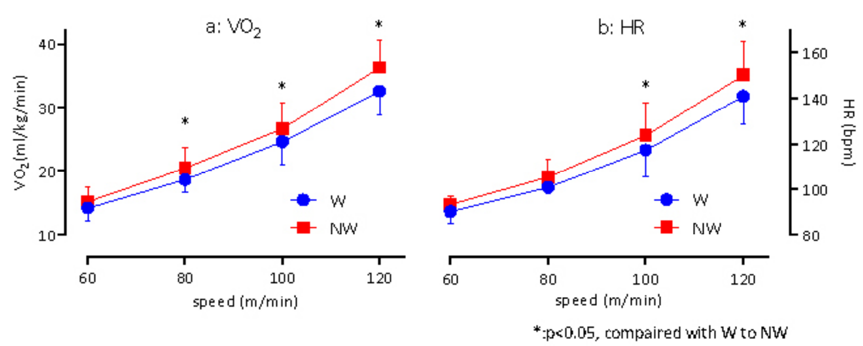


Figure 3. *Time-course of Power (a), Total Work Load (b), VO_2 (c) and HR (d) in Supramaximal Ex I*

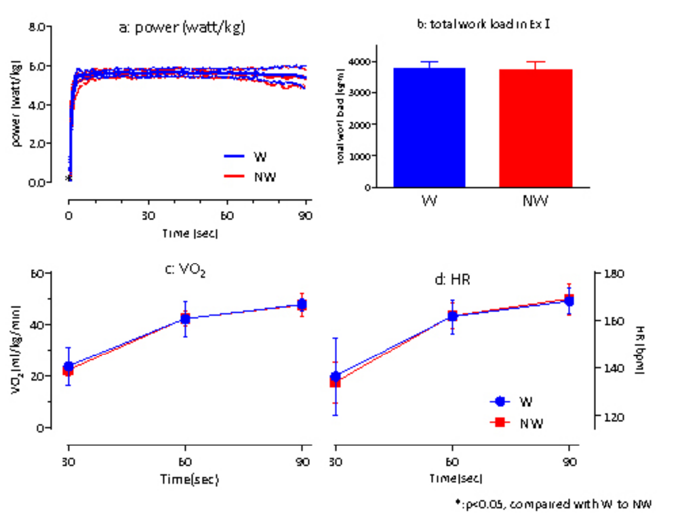
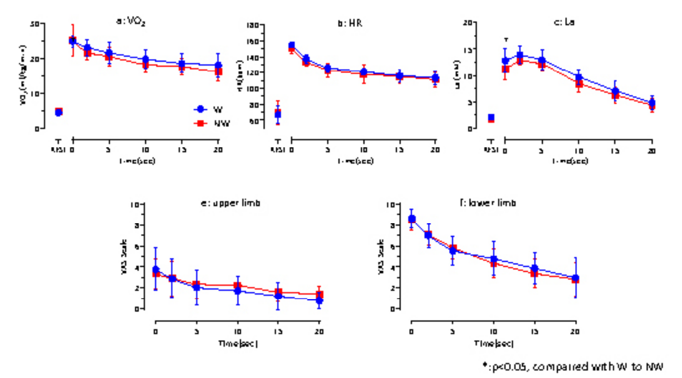


Figure 4. *Changes of VO_2 (a), HR (b), La (c) and VAS Scale (upper limb: d and lower limb: e) during AR*



rest, immediately after Ex I, and up to 20 min after AR indicated that although the values tended to be lower in NW than in W, the differences were not statistically significant (Figures 4a and 4b).

The maximum La levels for NW immediately after the main exercise until 5 min after the exercise were significantly lower than those for W (11.6±0.7 mM *vs.* 12.9±1.5 mM; $p<0.05$). La levels for W and NW after ≥10 min of exercise indicated that there were no significant differences between the values for N and NW, although the values were lower for NW than for W (Figure 4c).

No statistically significant differences were observed between the two groups in terms of VAS scores (Figures 4d and 4e), which indicated localized fatigue of the upper and lower limbs during AR activity.

Ex II: The total work values for W and NW calculated for Ex II were 3808.3±271.0 kg*m and 3779.3±258.6 kg*m, respectively, indicating that the work was similar for both the exercises (Figure 5d). The power values during Ex II were significantly lower for NW within 1 s after starting the activity, as observed in main exercise I ($p<0.05$; Figure 5a). No statistically significant differences were observed between VO_2 (Figure 5b) or HR (Figure 5c) for W and NW during Ex II.

Blood LA levels after the main exercises: La levels immediately after completing Ex I for W and NW were 12.8±2.3 and 11.1±1.8 mM, respectively, which were not significantly different from La values immediately after completing Ex II. (W: 12.9±3.0 mM; NW, 12.1±1.7 mM; Figure 6).

AT: After Ex II, the participants performed AT, which consisted of three sets of full-power bicycle pedaling for 10 s using the PowerMax VIII as the default program. The first attempt was designated as step 1, second as step 2, and third as step 3. The maximum anaerobic power values for W and NW as calculated based on AT were 13.70±1.1 watt/kg and 14.5±1.0 watt/kg, respectively, indicating that the values for NW were significantly higher than those for W ($p<0.05$; Figure 7a). The comparison of the actual measured values indicated that the maximum power for steps 1-3 during W

Figure 5. *Time-course of Power (a), Total Work Load (b), VO_2 (c) and HR (d) in Supramaximal Ex II*

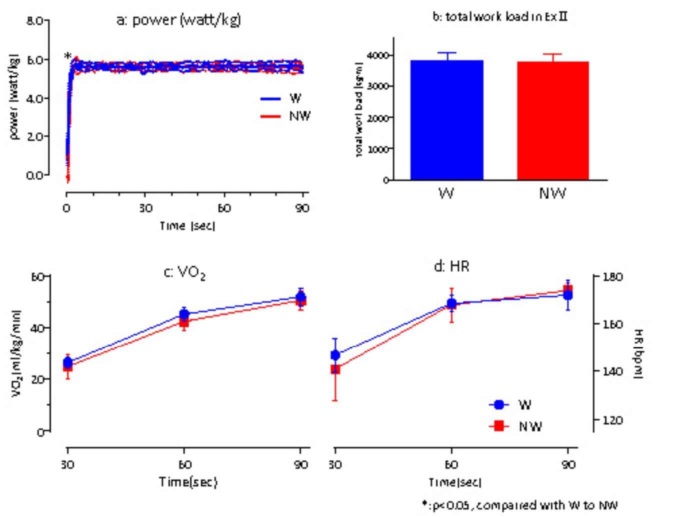


Figure 6. *La after each Supramaximal Exercise Test*

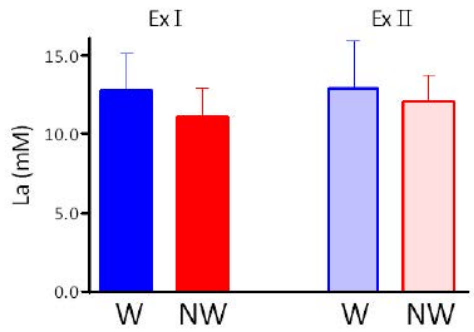


Figure 7. *Total Work Load (a), Work Load in each STEPs (b) and Time-course of Power of each STEPs (c) in Anaerobic Power Test*

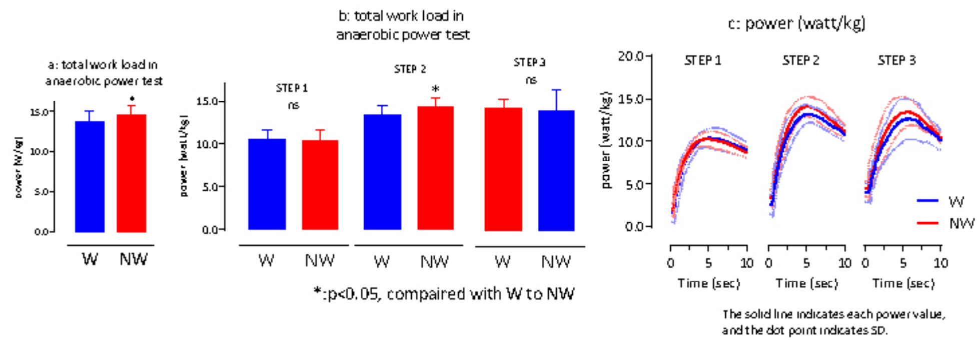
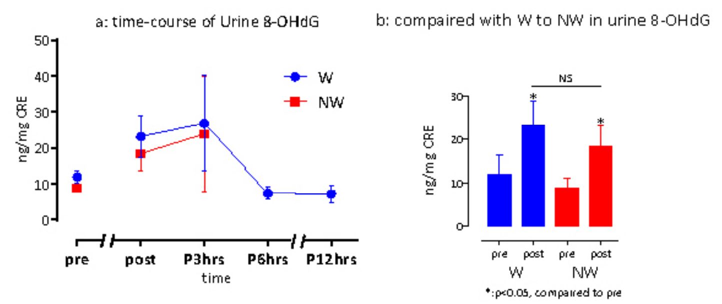


Figure 8. *Time-course of Urine 8-OHdG (a) and compared with W to NW in Urine 8-OHdG (b)*



was 10.50±0.9 watt/kg (step 1), 13.4±0.9 watt/kg (step 2), and 13.0±2.0 watt/kg (step 3), whereas during NW was 10.4±1.1 watt/kg (step 1), 14.3±0.8 watt/kg (step 2), and 13.9±2.4 watt/kg (step 3), respectively (Figure 7b). The maximum power for step 2 was significantly higher during NW than during W ($p<0.05$). Figure 7c shows the variations in the power values at all the steps.

Urinary 8-OHdG activity: Figure 8a shows the changes in urinary 8-OHdG levels prior to Ex I until 12 h post-exercise (next morning). The levels were approximately two-fold higher after the main exercises than those before for both the exercises. The maximum values were obtained 3 h after the exercise, which returned to baseline levels after 6 h. The pre-exercise 8-OHdG levels for W and NW were 12.0±4.3 and 8.8±2.3 ng/mg/CRE (NS),whereas the levels immediately after the exercises were 23.2±5.7 and 18.4±4.7 ng/mg/CRE (NS), respectively, indicating a significant increase after the exercises. However, no significant differences were observed between the groups (Figure 8b). Although not shown in the data, no statistically significant differences were observed between the pre- and post-maximal exercise test urinary 8-OHdG levels for the aerobic exercise.

DISCUSSION

This study aimed to investigate the physiological responses to a performance test during and after recovery to elucidate the AR effect of NW performed after supramaximal exercise.

VO_{2max} measured for the maximal exercise test performed by the participants was 54.1±2.6 mL/kg/min, regardless of the fact that it was performed on a cycle ergometer. VO_{2max} measured using a cycle ergometer is approximately 10% lower than that measured using a treadmill, because the cycle ergometer values measure localized exercise.[13] Based on this fact, we anticipated that the value measured when using the treadmill would be approximately 60 mL/kg/min, as the participants were individuals with a high degree of physical strength. The intensity levels of Ex I and II were calculated by extrapolating the work at an intensity of 120% VO_{2max} using relative expression (primary regression equation) of the load (kp) and %VO_{2max} measured during the Ex test. The load value was then recalculated for pedaling at 120 rpm for 90 s. More fast muscle fibers were mobilized when the pedaling speed was increased over 90 rpm; thus, by increasing glycolysis, the exercise activity promoted lactate acid metabolism. Therefore, we set the main exercises at parameters of 120 %VO_{2max}, 120 rpm, and 90 s because we believed that these parameters would be appropriate for investigating the AR effect on exercises involving sufficient mobilization of fast muscle fibers.

We investigated whether both the conditions during Ex I had the same performance level, and the results showed that the work values for Ex I (W, 3761.2±229.6 kg*m; NW, 3730.6±249.1 kg*m) did not significantly differ between the two conditions. Moreover, VO_2 and HR, which are physiological indices, increased over time under both the conditions ($p<0.001$), and no significant differences were observed between the conditions. Based on these findings, the effectiveness of AR and subsequent performance could be identified. Studies on W and NW tests indicated that VO_2, HR, and OMNI scores for both W and NW were consistent between the present and previous studies.[13] Moreover, these values significantly increased with increasing speed ($p<0.001$), and the speed maintained at 4 METs during NW (66.2±14.0 m/min) was significantly slower than that during W (73.1±12.3 m/min; $p<0.05$). With the use of an exercise that involves different body weight support for AR activity, we selected conditions with different AR intensities for the main exercises. The major difference between the two conditions was the fact that W was mainly a lower limb exercise, whereas NW was a more systematic exercise which mobilized both the trunk and upper limbs. NW has a larger stride than W, and therefore, it can be performed at a lower speed even at the same intensity as that of W. Furthermore, it can be assumed that in NW, there is less load on the lower limbs.[14,15,17] Because NW mobilizes the muscles of the trunk and upper limbs, which are less utilized when performing the main exercise of pedaling with lower limbs at rest, there may be differences in AR effects for W and NW despite being performed at the same intensity.

No significant differences were found between the two conditions in terms of VO_2 and HR. The investigation of all the parameters, regardless of the fact that the exercises were performed at the same intensity, indicated that La levels peaked immediately after completing the main exercise until 5 min after the exercise and significantly declined under both the conditions ($p<0.05$). However, although the performance was similar during both the exercises, during Ex I, the La peak during W was significantly higher than that during NW (p<0.05), and it later reached the same level. These differences in La peaks may be attributed to the speed at which La was released into the bloodstream and its reuse (the lactate shuttle) in the protagonist muscles.[6,7] The lactate produced by fast muscle fibers is released into the bloodstream and then circulates throughout the body. However, as the protagonist muscles worked at a relatively low intensity during NW, there may be an increased substrate utilization of lactate by slow muscle fibers when the muscles of the upper limbs and trunk were simultaneously utilized.[19] The actual HR during AR was slower in NW than in W; However, both the rates were approximately similar. When vigorous arm movements are added to leg exercises, both the blood flow in the upper limbs and oxidation in the muscles decline,[19] therefore, individuals with weak upper limb muscles experience overload during NW.[20] Further studies on the appropriate setting of load intensity must be conducted.

The comparisons of post-AR performance tests indicated that total work, VO_2, HR, and power fluctuations over time did not significantly differ between the two conditions during Ex II. The results of subsequent performance tests indicated that there were significantly higher maximum AT values for NW than for W (p<0.05). Moreover, significant differences were observed between steps 1 and 3, and the maximum power value at step 2 was significantly higher for NW than for W. This indicated that the amount of La energy exerted with respect to the anaerobic energy supplied plays a major role during NW. Specifically, our findings suggested that AR in the form of NW contributes to energy recovery in the La system. During NW, a better blood supply was maintained in the upper limbs and trunk than during W. Thus, La reuse was effective, and as the load was distributed to the upper limbs and trunk, the total load on the lower limbs decreased. This was the major reason for the improvement in performance. Moreover, during exercise, the blood flow is redistributed to the protagonist muscles[3]; therefore, during supramaximal exercise, hepatic blood flow volume and La glyconeogenesis *via* the Cori cycle decrease.[21] Nevertheless, because systemic blood flow increases during NW, slow muscle fibers are utilized, and the myocardium allows a more effective energy recovery during W, which is then used for subsequent performance.

The results of our urinary 8-OHdG activity measurements, which were used as an index of stress induced by anaerobic exercise, indicated that there were no significant differences between the two conditions during W and NW. However, the activity significantly increased after the exercise. Increased 8-OHdG activity was maintained at a high-level until 3 h after the exercise. However, after 6 h, it returned to the resting level. Urinary 8-OHdG activity is affected by the type of exercise, and it does not significantly increase during aerobic exercises.[22, 23]

Finally, the use of NW as an AR exercise led to high maximum power values in step 2 during AT. This suggested that NW contributed to energy recovery in the La system. Future studies on the association between increased intensity of the main exercise, conditions that increase La metabolism, upper limb muscle strength, and body composition must be conducted to elucidate the efficacy of NW as a form of AR exercise.

Although the number of cases in this study is small, it is a new finding that sufficient direction can be shown in the effectiveness of active recovery by Nordic walking.

However, as an experimental limitation, there is a need to conduct a more practical examination and there is a need for examining by increasing the number of subjects under practical measurement conditions.

CONCLUSION

By mobilizing the upper limb and trunk muscles, which are utilized sparingly when the protagonist muscles of the lower limbs are resting after performing Ex I (lower limb exercise), we investigated the speed of recovery. The results indicated that although there were no significant differences between the two conditions during Ex II, which was a similar exercise performed after Ex I, same amount of work was performed in both the exercises. However, the maximum anaerobic power of the performance test performed after the pretest was significantly higher for NW. The maximum power value for step 2 was high, which suggested that it played a role in the energy recovery of the La system.

ACKNOWLEDGEMENT

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CONFLICTS OF INTEREST

There are no specific companies and or organizations in conflict of interests to be disclosed in present research.

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A Retrospective and Comparative Analysis of the Physical Fitness of Custody Assistant Classes Prior to Academy Training

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ABSTRACT

Background
Within a law enforcement agency (LEA), custody assistants (CAs) are responsible for upholding proper safety and security inside correctional facilities. However, unlike other law enforcement positions, CAs may not be subjected to fitness testing prior to matriculation. If there are differences in fitness between recruits across different classes, this could influence training adaptations following academy.

Purpose
The purpose of this study was to investigate the physical fitness of CAs across three different academy classes.

Methods
A retrospective examination of performance data was conducted on 108 CAs from three classes (Class 1: males=29, females=11; Class 2: males=22, females=16; Class 3: males=18, females=12). The fitness tests encompassed: number of push-ups and sit-ups in 60 seconds; 201-meter (m) and 2.4-kilometer (km) run times; and estimated maximal aerobic capacity (VO_{2max}) derived from the 2.4-km run. To compare males and females from the classes (the sexes were analyzed separately), a one-way analysis of variance-with Bonferroni post hoc was utilized ($p<0.05$). Effect sizes (d) were also calculated.

Results
Class 2 males executed significantly more sit-ups than those from Class 3. There were moderate effects for the greater number of push-ups completed by Class 2 compared to Class 3, and the faster 201-m run for Class 3 compared to Class 2 (d=0.60-1.00). There were no significant between-class differences for the females, but moderate effects for the greater sit-ups and estimated VO_{2max} for Class 1 compared to Class 3 (d=0.64-0.76).

Conclusion
Even without physical testing prior to academy, the CA classes from this LEA seemed to be relatively similar in fitness. However, physical training instructors should acknowledge that there may be select variances between certain classes (e.g. abdominal strength measured by sit-ups; anaerobic endurance measured by the 201-m run). Instructors should utilize appropriate assessments to characterize fitness of their recruits, and where possible, tailor training accordingly.

Keywords
Aerobic capacity; Anaerobic endurance; Correctional officers; Police; Strength endurance; Tactical.

INTRODUCTION

Custody assistants (CAs) are law enforcement personnel that assist law enforcement officers (LEOs) and deputies with maintaining safety and security in custody detention, station jails, or court lockup facilities. Although CAs tend to support the work of LEOs at the detention facilities, they still may be required to perform extraordinary physical activity during a work shift.[1] Some of the more important tasks for CAs include the searching of cells, responding to alarms to assist colleagues, physical confrontations which could involve control and restraint of an inmate, or the need to pursue and corral an inmate attempting to evade restraint.[2,3] Tasks such as emergency response and inmate confrontations could potentially be very physically taxing for a CA, and could endanger the safety and well-being of the CA, their colleagues, and other inmates. Accordingly, it has been recognized that correctional populations should have an acceptable level of strength, endurance, flexibility, and general fitness to complete the tasks demanded of them.[2,3]

Despite the importance of physical health and fitness for a CA, depending on the agency, applicants for a CA position may not need to complete any physical fitness testing prior to matriculation.[4] Fitness testing is typically used by a law enforcement agency (LEA) to ensure that they find candidates that have the requisite physical abilities to complete job-specific training and the tasks required in the occupation. Not incorporating any physical testing prior to matriculation, in addition to the non-discriminatory hiring practices adopted by most LEAs,[5] could mean that the pool of potential qualified CA recruits is greater. This increase in pool size may be of benefit to the LEA in terms of increasing their ability to select the most viable recruits and as a means to fill any vacant positions. However, a possible by-product of this approach is that the number of potential qualified individuals, and the resulting accepted recruits, may have very different fitness levels prior to commencing the academy training period.

Academy is where LEA instructors will train recruits so that they can tolerate the physical rigors of the profession, while also teaching the necessary procedures required for the job.[6-8] Specific to CAs, some examples would be completing physical training (PT) to develop base aerobic and anaerobic fitness for job-related tasks, defensive tactics training to learn specific inmate restraint techniques and self-defense, and learning the proper procedures for processing and supervising inmates, conducting cell searches, and other CA-specific responsibilities. These teaching units are commonly taught in a standardized manner, in order to meet the requirements of the LEA and state in which the LEA is based. In accordance with this, and with specific reference to PT, many agencies will adopt a one-size-fits-all approach.[8-10] What this means is that all recruits within a class will complete a standard set of exercises and activities, regardless of any pre-existing fitness or ability levels. This approach is often adopted due to the time constraints associated with academy, the number of recruits within a class relative to the number of PT instructors, and the fact that job tasks will remain the same regardless of the age, sex, and fitness of the CA. Nevertheless, this approach could be problematic if the recruits in a class vary greatly in their levels of fitness. For example, in law enforcement officers, numerous studies have shown inherent differences in fitness between males and females as shown by performance in assessments such as the maximum number of push-up in 60 seconds (sec), vertical jump, and 2.4 kilometer (km; 1.5 mile) run.[5,11-13] This could potentially lead to a higher rate of injury in females if they are required to complete the same level of training as males, which has been shown to occur in recruits from the military.[14] Further, age may also have an impact on the physical fitness of law enforcement populations.[11,12] From a training perspective, even though there may be set curriculum and expectations for PT, the same training stimulus may not be optimal for all recruits to meet the same required end of course performance standard. This could be especially true if the fitness levels of CA recruits vary considerably.

The intensities of specific training units within a PT session (e.g. circuit training, calisthenics, formation runs) is generally dependent on the overall fitness of the class.[9,10] For example, it can be observed that during a PT session, such as a formation run (a long, slow distance run where the class stays in an organized formation along a set route),[9] the intensity is generally set towards those recruits of lesser fitness. This is done in attempt to ensure that the class stays in formation for the duration of the run. Nonetheless, modifying training intensity towards the bottom end of a class is an issue, because if an inappropriate load is applied, this can result in under-training for more fit recruits.[15] It should also be noted, however, that adjusting training intensity towards more fit recruits can also be problematic, as too great an intensity-for less fit individuals could lead to over-training and an increased risk of injury.[15-17] Orr and Moorby[18] demonstrated the limitations of group training in Australian Army recruits where heart rates for a given group endurance marching session had some recruits working above 180 beats per minute, and others at approximately 150 beats per minute. In an investigation of a standardized formation run where individual fitness can be reflected in the heart rate response in CA recruits, Cesario et al.[9] noted that the heart rate responses varied between high, moderate, and low fitness recruits. Collectively, these results suggest that different training stimuli are being applied to individuals within the one group session.

There is currently no research that has demonstrated the pre-existing fitness levels of CA recruits in typical tests for law enforcement populations prior to academy training. This is important information to document, as it could help dictate program design for practitioners and PT instructors who work with CAs and custody populations. Given the previous research has recommended individualized[19] and ability-based training[8-10] for law enforcement populations to enhance fitness and prevent injury, information such as this could dictate whether this approach is relevant in CA recruits. Therefore, the purpose of this study was to investigate the characteristics of CAs from three different classes prior to academy training. It was hypothesized that there would be significant differences between these assessments (number of push-ups and sit-ups, 201-meter [m] and 2.4-km run times) across the different CA classes. This would be true when considering the overall means for the classes, and for both males and females.

METHODS

Participants

Data were collected by the training staff of one LEA from the USA and were released with consent from that organization. A sample of convenience comprised of 108 CA recruits (age: 27.91±6.87 years; body mass: 75.59±15.73 kg), which encompassed all recruits from three academy classes. The academy training period for each of the three classes was conducted separately over the time period from December 2016 until May 2017, but all occurred at the same facility. The sample included 69 males (age: 27.54±6.74 years; body mass: 81.27±15.22 kg) and 39 females (age: 28.56±7.13 years; body mass: 65.68±11.11 kg). Similar to previous research on tactical populations,[12,20,21] only age and body mass data were available for the description of the participants. Based on the archival nature of this analysis, the institutional ethics committee approved the use of pre-existing data (HSR-17-18-370). Regardless, the study still conformed to the recommendations of the Declaration of Helsinki.

Procedures

The data utilized in this study were collected by the CA training staff of one LEA using the procedures that are detailed. Instructors who held a Tactical Strength and Conditioning Facilitator (TSAC-F) certification from the National Strength and Conditioning Association in the USA verified the proficiency of the staff. All testing was conducted in the first week of academy training for each CA class in the order presented here. This typically occurred between the times of 0600-0700. The push-up and sit-up tests were conducted outdoors at the start of one physical training session at the LEA's training facility. The 201-m and 2.4-km run were performed on an athletics track at the LEA's facility.

Push-up Test

Upper-body strength endurance was assessed via a maximal push-up test where recruits completed as many repetitions as possible in 60-sec. The protocol for this assessment followed that of established research.[6,11,12,20-22] The recruits started in the 'up' position, with their body taut and straight, their hands positioned shoulder-width apart, and their fingers pointed forwards. A partner placed a fist on the floor directly under the recruit's chest, which ensured that the recruits descended to an appropriate depth. On the start command, the tester began the stopwatch and the recruit lowered themselves until their chests contacted their partner's fists, before returning to the start position. The recruits performed as many push-ups as possible using this technique in the allotted time period. Recruits could rest in the up position with straight arms, but only full repetitions were recorded.

Sit-up Test

Strength endurance of the abdominal muscles was assessed *via* the sit-up test, where the recruits completed as many repetitions as possible in 60-sec.[6,11,12,21,22] The recruits laid on their backs with their knees flexed to 90°, heels flat on the ground, and hands cupped behind their ears. The feet were held to the ground by a partner during the test. On the start command, recruits raised their shoulders from the ground while keeping their hands cupped at their ears and touched their elbows to their knees. The recruit then descended back down until their shoulder blades contacted the ground, and completed as many repetitions as possible in the allocated time period. Recruits could rest in the up position, but only full repetitions were counted.

201-m (220-yard) Run

The 201-m run has been used previously in physical assessment batteries of firefighters,[23] and was adopted by the PT instructors in this study. A running test over this distance provided a measure of anaerobic capacity.[24] The 201-m distance was marked on the athletics track, and the recruits were instructed to run the distance as quickly as possible. The recruits completed the runs in their platoons (groups of between 8-12 recruits). Time for each recruit was recorded to the nearest 0.10 sec by a handheld stopwatch, a common practice in law enforcement testing.[6,11,12,21] Test administrators trained in the use of stopwatch timing procedures, which the PT instructors were, can record reliable data.[25]

2.4-km (1.5-mile) Run

The 2.4-km run was used to assess aerobic capacity and is commonly used for this purpose in tactical populations.[6,11,12,21,22] The test was performed on an athletics track where the recruits were required to complete six laps of the 400-m track as quickly as possible. The 2.4-km run time was recorded for each recruit on a handheld stopwatch to the nearest 0.10 sec, and the final run time was recorded in minutes: seconds (min: sec). Maximal aerobic capacity (VO_{2max}) was estimated for male and female recruits via the following equations,[26] and expressed in milliliters of oxygen consumed per kg body mass per min ($ml.kg^{-1}.min^{-1}$):

Male VO_{2max} ($ml.kg^{-1}.min^{-1}$)=91.736-(0.1656 x body mass)-(2.767 x 2.-km run time in min).

Female VO_{2max} ($ml.kg^{-1}.min^{-1}$)=88.020-(0.1656 x body mass)- (2.767 x 2.4-km run time in min).

These equations were used as the sample population in this study had a mean age that fell within the range detailed by George et al.[26]

Statistical Analysis

All statistical analyses were computed using the Statistics Package for Social Sciences (Version 24.0; IBM Corporation, New York, USA). Descriptive statistics (mean±standard deviation [SD]; 95% confidence intervals [CI]) were calculated for each test parameter. A one-way analysis of variance (ANOVA), with Bonferroni post hoc adjustment for multiple pairwise comparisons, was used to calculate any differences between the different classes, with males and females analyzed separately. Statistical significance was set at p< 0.05 a priori. Effect sizes (d) were also calculated for the between-group comparisons, where the difference between the means was divided by the pooled SD.[27] In accordance with Hopkins,[28] a d less than 0.2 was considered a trivial effect; 0.2 to 0.6 a small effect; 0.6 to 1.2 a moderate effect; 1.2 to 2.0 a large effect; 2.0 to 4.0 a very large effect; and 4.0 and above an extremely large effect. As described by Lockie et al.[29] effect sizes were included in this research to provide useful and practical information. Furthermore, scatter plots were also produced for each fitness test to derive the spread of scores relative to the individual CA recruit from each class.

RESULTS

The descriptive data for the overall class means is shown in Table 1, and there were no significant differences between the classes when male and female data was combined for any of the assessments (p=0.093-0.998). All between-class effect sizes for the comparisons were trivial-to-small (Table 2). Descriptive data for the male and female CA recruits from the three classes is shown in Table 3, while the pairwise effect size data for the males and females is displayed in Tables 4 and 5, respectively. With regards to the males, there were no significant differences between the three classes in age, body mass, number of push-ups, 2.4-km run time, or estimated VO_{2max} (p=0.154-0.946). There was a moderate effect size for the greater number of push-ups completed by Class 3 compared to Class 2, although the difference was not significant (p=0.366). The initial one-way ANOVA suggested that there were significant differences in the number of sit-ups (p=0.035) and 201-m run time (p=0.047). The post hoc analysis revealed that the males from Class 2 completed significantly more sit-ups compared to the Class 3 males (24%; p=0.042), which had a moderate effect size. Regarding the 201-m run, the post hoc revealed that there were no significant between-group differences, although the faster time for Class 3 approached significance when compared to Classes 1 (18%; p=0.086) and 2 (19%; p=0.079). There was also a moderate effect size for the difference between Classes 2 and 3.

Table 1. *Descriptive Data (mean±SD; 95% CI) for all Custody Assistant Recruits from Three Classes Prior to Academy Training*

	Class 1 (n=40)	Class 2 (n=38)	Class 3 (n=30)
Age (years)	27.30±6.17 (25.33-29.27)	27.34±6.47 (25.22-29.47)	29.43±8.14 (26.39-32.47)
Body mass (kg)	76.87±18.13 (71.08-82.67)	74.92±14.43 (70.11-79.74)	76.82±14.70 (71.33-82.31)
Push-ups (no.)	31.08±16.09 (25.93-36.22)	29.34±14.16 (24.69-34.00)	33.27±15.30 (27.55-38.98)
Sit-ups (no.)	37.70±8.83 (34.88-40.52)	39.82±16.25 (34.47-45.16)	33.30±9.98 (29.57-37.03)
201 m run (sec)	36.40±10.87 (32.92-39.88)	37.84±8.29 (35.12-40.57)	33.30±8.96 (29.96-36.64)
2.4 km run (min:sec)	14:29±3:39 (13:19-15:39)	14:29±2:29 (13:40-15:19)	14:27±2:53 (13:21-15:33)
VO_{2max} (ml•kg^{-1}•min^{-1})	38.57±11.49 (34.89-42.24)	37.50±9.40 (35.48-40.71)	37.50±9.40 (34.00-41.01)

Table 2. *Pairwise Effect Size Data for all Custody Assistant Recruits from Three Classes Prior to Academy Training*

	Class 1 – Class 2	Class 1 – Class 3	Class 2 – Class 3
Age	0.01	0.29	0.28
Body mass	0.12	0.00	0.13
Push-ups	0.11	0.14	0.27
Sit-ups	0.16	0.47	0.48
201 m run	0.15	0.31	0.53
2.4 km run	0.00	0.01	0.01
VO_{2max}	0.10	0.10	0.00

Table 3. *Descriptive Data (mean±SD; 95% CI) for Male and Female Custody Assistant Recruits from Three Classes Prior to Academy Training*

	Males			Females		
	Class 1 (n=29)	Class 2 (n=22)	Class 3 (n=18)	Class 1 (n=11)	Class 2 (n=16)	Class 3 (n=12)
Age (years)	26.90±5.77 (24.70-29.09)	27.77±5.65 (25.27-30.28)	28.28±9.29 (23.66-32.90)	28.36±7.31 (23.45-33.28)	26.75±7.60 (22.70-30.80)	31.17±5.98 (27.37-34.37)
Body mass (kg)	82.60±17.68 (75.87-89.33)	81.68±13.37 (75.59-87.76)	81.10±14.18 (74.05-88.15)	61.77±7.75 (56.56-66.98)	66.06±10.68 (60.37-71.75)	70.40±13.55 (61.79-79.01)
Push-ups (no.)	36.14±14.46 (30.64-41.64)	36.91±10.35 (32.32-41.50)	42.94±9.71 (38.12-47.77)	17.73±12.41 (9.39-26.06)	18.94±12.05 (12.52-25.36)	18.75±9.41 (12.77-24.73)
Sit-ups (no.)	38.00±9.22 (34.49-41.51)	43.91±13.94 (37.73-50.09)	35.50±6.91* (32.07-38.93)	36.91±8.08 (31.48-42.34)	34.19±17.93 (24.63-43.74)	30.00±13.00 (21.74-38.26)
201 m run (sec)	35.51±12.35 (30.82-40.22)	36.00±4.13 (34.17-37.83)	29.17±8.71 (24.84-33.50)	38.73±5.04 (35.34-42.11)	40.38±11.57 (34.22-46.54)	39.50±4.95 (36.36-42.64)
2.4 km run (min:sec)	14:21±4:04 (12:49-15:54)	13:46±2:19 (12:44-14:48)	13:15±2:04 (11:44-14:45)	14:50±2:18 (13:17-16:22)	15:29±2:26 (14:11-16:47)	16:09±1:48 (15:00-17:18)
VO_{2max} (ml•kg^{-1}•min^{-1})	39.22±12.84 (34.34-44.10)	40.85±7.56 (37.50-44.20)	41.32±9.26 (36.71-45.92)	36.85±7.02 (32.13-41.56)	34.31±7.02 (30.56-38.05)	31.78±6.38 (27.73-35.84)

*Significantly (p<0.05) less than Class 2.

Table 4. *Pairwise Effect Size Data for Male Custody Assistant Recruits from Three Classes Prior to Academy Training*

	Class 1 – Class 2	Class 1 – Class 3	Class 2 – Class 3
Age	0.15	0.18	0.07
Body mass	0.06	0.09	0.04
Push-ups	0.06	0.55	0.60*
Sit-ups	0.50	0.31	0.76*
201 m run	0.05	0.59	1.00*
2.4 km run	0.18	0.31	0.19
VO_{2max}	0.15	0.19	0.06

*Moderate effect for the pairwise comparison.

Table 5. *Pairwise Effect Size Data for Female Custody Assistant Recruits from Three Classes Prior to Academy Training*

	Class 1 – Class 2	Class 1 – Class 3	Class 2 – Class 3
Age	0.22	0.42	0.65*
Body mass	0.46	0.78*	0.36
Push-ups	0.10	0.09	0.02
Sit-ups	0.20	0.64*	0.27
201 m run	0.18	0.15	0.10
2.4 km run	0.28	0.64	0.31
VO_{2max}	0.36	0.76*	0.38

*Moderate effect for the pairwise comparison.

There were no significant differences between classes for the female CA recruits in age, body mass, or any of the fitness assessments (p=0.184-0.961). There were moderate effect sizes for the greater age for Class 3 compared to Class 2, and body mass for Class 3 compared to Class 1, but both were non-significant (p=0.331 and 0.203, respectively). There were also moderate effect sizes for the 23% greater number of sit-ups and 16% higher estimated VO_{2max} for Class 1 compared to Class 3, but again, these were non-significant (p=0.761 and 0.253, respectively).

Figures 1 through 3 display the individual scores for each CA recruit from the three classes in the push-up and sit-up test, 201 m and 2.4 km run, and estimated VO_{2max} from the 2.4 km run, respectively. The scores in the push-up test ranged from a low of 0 repetitions to a high of 64 repetitions across the three classes. The sit-up test also had a low of 0 repetitions, and a high of 90 repetitions. The 201 m run time had a slowest time of 95 sec, and a fastest time of 25 sec. The 2.4 km run time had a slowest time of 31:35 min:sec (1895 sec), and a fastest time of 9:59 min:sec (599 sec). Finally, the lowest estimated VO_{2max} from the three classes was 15.84 $ml \cdot kg^{-1} \cdot min^{-1}$, and the highest was 55.81 $ml \cdot kg^{-1} \cdot min^{-1}$.

Figure 1. *Individual Scores for the Push-Up (A) And Sit-Up (B) Tests in Male and Female Custody Assistant Recruits from Three Classes Prior to Academy Training*

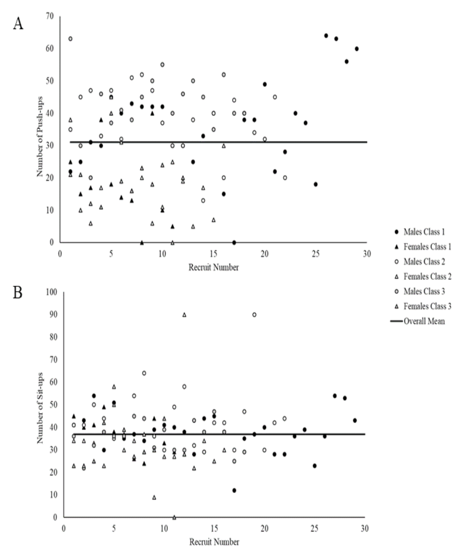


Figure 2. *Individual Times for the 201 M (A) and 2.4 Km (B) Runs in Male and Female Custody Assistant Recruits from Three Classes Prior to Academy Training*

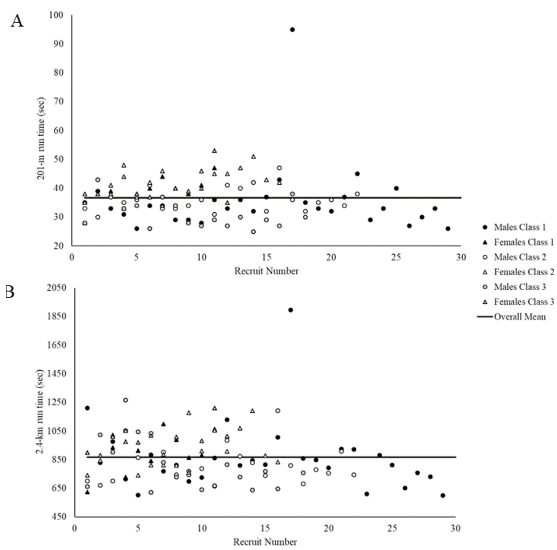
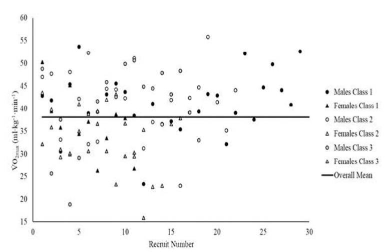


Figure 3. *Individual Estimated VO_{2max} from the 2.4 Km Run in Male and Female Custody Assistant Recruits from Three Classes Prior to Academy Training*



DISCUSSION

This study investigated the physical fitness characteristics of CA recruit classes prior to academy training. Physical testing may not be required prior to matriculation into academy for certain LEAs,[1] which could result in classes that are different in their physical fitness levels prior to training. The results from this study suggested that even without pre-employment testing, the fitness characteristics of CA recruits across three classes were relatively similar for both males and females when considering overall mean data (both select differences for males (strength endurance as measured by push-ups and sit-ups, and anaerobic capacity as measured by 201-m run time) and females (abdominal strength as measured by sit-ups and estimated VO_{2max} derived from the 2.4-km run) between the classes. Any differences in fitness between recruit classes suggests that a 'one-size-fits-all' approach to academy training may be less than optimal, and ability-based training could be explored in this population.[8-10]

Physical fitness testing is often used by LEAs to in an attempt to find recruits that are capable of completing training and tasks specific to the occupation, while also not discriminating against individuals on the basis of age, sex, and ethnicity.[5] The non-inclusion of physical testing could expand the potential candidate pool, but may mean that a great range of fitness levels would be present in recruit classes. Specific to CAs, the results from this study suggested that when considering the overall mean data for male and female recruits, there were relatively few differences between the three classes. These results further suggest that the hiring practices adopted by this LEA, which include an initial application, written test, background checks, and medical and psychological evaluations,[1] can result in classes with relatively similar fitness characteristics, as measured by maximal push-ups and sit-ups, and 201-m and 2.4-km runs. However, when considering individual results, it was evident there was a great spread of fitness across the recruits from each of the classes as measured by each test. Further to this, the spread of individual scores resulted in select differences between the classes for both the males and females.

Recognizing potential fitness differences for individual recruits in CA academy classes is important for practitioners and PT instructors, as individualized training programs have been recommended for law enforcement populations.[19] Indeed, if there is variation in fitness for individuals within a class, adopting a 'one-size-fits-all' model of training may not be optimal. As an example, this is an issue with formation runs in CA recruits[9] and endurance marching in army recruits,[18] as the same relative workload results in different intensities amongst individuals. With regards to the females, there was a moderate effect size for the higher estimated VO_{2max} from the 2.4-km run for Class 1 compared to Class 3. Further, for both the male and female recruits, there was a spread of scores for both the 2.4-km run time and estimated VO_{2max} when considered specific to each individual across the three classes. This is a particular issue as the male and female recruits train together, and this could increase the risk of injury for the females.[14]

Orr et al.[8] analyzed ability-based training for running in Australian police recruits, and found that this could be a more time-efficient way to develop aerobic conditioning when compared to a more traditional interval running model, as measured by the 30-15 intermittent fitness test. Furthermore, Orr et al.[8] found a reduced rate of injury in ability-based training groups when compared to police recruits who completed interval running not based on ability (4-6% *vs.* 10-14% of the respective groups). While the previous examples involve police recruits, in military recruit training sudden increases in training loads have been is associated with an increased risk of injury.[30] Similarly, inappropriate application of training load can further contribute to an increased risk of injury,[15] which could occur in interval training that is not based on the fitness level of individuals or smaller ability-based groups. Given the potential variations in aerobic fitness that could exist between individual CA recruits, ability-based running training could be incorporated into academy training with the dual goals of increasing fitness while also reducing the probability of injury. The effects of this type of training approach requires further investigation in tactical populations.

If ability-based training is appropriate for aerobic conditioning in law enforcement recruits,[8] it could also be appropriate for anaerobic-based training as well. Select differences were seen in tests that emphasized anaerobic capacity for the CA recruits in this study. The males in Class 2 completed significantly more sit-ups compared to Class 3, and there were moderate effect sizes for the greater number of push-ups completed by Class 2 compared to Class 3, and the faster 201-m run time for Class 3 compared to Class 2. With regards to the females, there was a moderate effect size for the greater number of sit-ups for Class 1 compared to Class 3. Further to this, the spread of individual scores in the push-up test, sit-up test, and 201-m run highlights discrepancies between individual CA recruits, which is some cases was very marked. For example, there were CA recruits who could not complete a push-up or sit-up prior to academy, and there was one recruit who took more than 90-seconds to complete the 201-m run. This could be a major issue for these recruits, as a lack of strength and anaerobic capacity could negatively affect their ability to complete essential job tasks (e.g. response to emergencies, inmate pursuit and restraint).[2,3] Furthermore, given these differences in initial fitness levels, ability-based anaerobic training should be a consideration for TSAC-F and training instructors.

Some of the challenges for implementing ability-based strength and anaerobic training is the absence of equipment and appropriate training space at LEA facilities. The use of alternative implement training (e.g. sand bags, kegs, tires, battle ropes) could be utilized if there is a lack of traditional resistance training equipment and gym space.[31,32] This would allow for ability-based strength and anaerobic-focused training to occur outdoors if required, and resistance could still be manipulated (e.g. via degree of resistance, volume, sets, repetitions, and rest periods) depending on the ability level of recruits. Circuit training could be adopted where factors such as these could be manipulated by instructors relative to the ability of the CA recruits.[10] Practitioners should attempt to individualize their training programs targeting strength, power, and anaerobic endurance as much as possible, within the confines of their equipment and location. This could lead to more optimal adaptations in fitness measures such as strength and anaerobic endurance in CA recruits. This should also be investigated further in law enforcement and tactical populations.

There are several study limitations that should be noted. The class sizes investigated in this study were not the same size, nor were the numbers of males and females in each class the same. However, class sizes are often dictated by the human resources division of a LEA, and by how many applicants can successfully complete the hiring process by class start dates. There was no data available on the pre-academy training habits of the CA recruits in this study, although potential recruits have no legal obligation to provide this information to LEA hiring or training staff. Further, the data analyzed in this study has practical relevance because these were actual CA classes from a LEA. This study did not detail whether fitness changed over the course of academy for each CA class specific to the training model used. Future studies should investigate whether fitness measures such as strength endurance, and anaerobic and aerobic capacity, improve over the course of academy in CA recruits. Furthermore, the implementation of traditional and ability-based training methods for CAs and correctional populations should be analyzed.

In conclusion, although the hiring practices of LEAs should result in CA academy classes of relatively similar characteristics of male and female recruits when considering mean data, there will be differences in fitness between individual recruits. This would suggest that a 'one-size-fits-all' model of training may not be the most optimal approach. In order to note any strengths and weaknesses of CA recruits, practitioners should use appropriate assessments to gauge the fitness characteristics of their classes. Following this, it is suggested that PT programs be individualized as much as possible, and based on the ability levels of the recruits. This could lead to PT being more time-efficient with more optimal changes in fitness for all recruits, while also reducing the risk of any injury that can occur via the inappropriate application of training load. Even though the job tasks of male and female CAs are the same following academy training, the prescription of ability-based training should better prepare each individual recruit so they will be able to all meet the same demands of the profession.

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CONFLICT OF INTEREST

None of the authors have any conflict of interest.

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Case Study

Cervical Strain/Whiplash Associated Disorder (WAD) Management

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ABSTRACT

Introduction: "Cervical strain and whiplash" secondary to a motor vehicle accident (MVA) are commonly treated in an emergency room and frequently referred to outpatient physical therapy care. Though, the Quebec Task Force on whiplash associated disorder (WAD) has provided clinical practice guidelines, due to low-level evidence available, the third aspect of evidence-based practice, namely, clinical expertise continues primarily to guide management of this diagnosis.
Purpose: This case analysis applies current evidence regarding the use of core stability training in WAD while also incorporating the World Health Organization's International Classification of Functioning, Disability and Health (ICF) Model in an elite athlete case.
Methods: Case study generated regarding an elite athlete who sustained whiplash/cervical strain injury status post motor vehicle accident. The patient care model was utilized to detail the application of evidence based practice.
Discussion: Discussion points to apply current evidence are integrated within each aspect of the patient care model, namely, Evaluation, Assessment, Diagnosis, Prognosis and Intervention.
Conclusions: Though low-level evidence has been available to support clinical management guidelines for management of whiplash, clinicians can refer to these guidelines while applying available evidence and clinical expertise for effective patient recovery.

Keywords: Cervical strain; Whiplash; Pain management.

INTRODUCTION

Cervical strain and whiplash are common diagnoses given to patients who sustain cervical pain after a motor vehicle accident (MVA) with whiplash being the most commonly treated emergency room diagnosis in the USA.[1] These patients are routinely seen by primary care physicians and can be referred to outpatient physical therapy (PT) care. The internationally recognized definition of whiplash injury according to the Quebec Task Force (QTF) on whiplash associated disorders (WAD), is an acceleration-deceleration mechanism of energy transfer to the neck may result from rear-end or side-impact motor vehicle collisions, but can also occur during driving or other mishaps.[2] The whiplash diagnosis is given to patients with cervical pain associated with MVA whether or not they have sustained the true quick flexion extension mechanism that defines a whiplash injury. In Quebec, the incidence rates for whiplash are reported as 70 per 100,000 individuals while this is reported as 106 per 100,000 in Australia. In the United Kingdom, 3 in 1,000 individuals will sustain a true whiplash injury per year.[3] There is also an increase in patients seeking healthcare for WAD in the last 30 years as greater than 3/1000 individuals in North America and Western Europe have sought care for whiplash injuries resulting from MVA.[1,4] Though cited costs vary, annual costs attributed to treatment of individuals who develop chronic symptoms and subsequent work loss in the UK is reported as 3 billion pounds per year and up to $230 billion in the USA.

Though the Quebec Task Force (QTF) on WAD was convened to provide clinical practice guidelines, the resultant document is critiqued as lacking rigor due to the dearth of high-level evidence available for review and selection bias in the methodology. The New South Wales Clinical Guidelines for the Management of WAD funded by the Motor Accidents Authority[5,6] was undertaken to update the QTF guidelines based upon more recent evidence, however encountered the limitation of low-level evidence and so also deferred to professional expertise of the panel for formation. Therefore, there exist clinical practice guidelines to assist the clinician in the management of WAD, however, clinical expertise continues as a critical component to patient management.

To demonstrate an application of clinical practice guidelines and use of clinical expertise the following is a Case Analysis, whereby a specific real-life situation is used to provide assessment and interpretation of the decisions made in the management of a cervical strain/whiplash injury. The line of reasoning and assessment of the assumptions made with this patient scenario are included following the data presented. In accordance with current clinical practice, the World Health Organization's International Classification of Functioning, Disability and Health (ICF) Model,[7] see Figure 1, is used as a framework for the holistic approach used with this patient case along with the Patient Management Model for PT Intervention that includes, Examination, Evaluation, Assessment, Diagnosis, Prognosis, Intervention.[8]

With regard to prognosis, various estimates are reported. The QTF concluded that most whiplash injuries are self-limiting and "short-lived",[2] however, other authors have found that between 14 and 42% of patients develop chronic symptoms for longer than 6 months and 10% of these have severe pain of a constant nature.[9] Other authors have estimated that the prognosis for patients with a true whiplash injury is "good" for 40% of the instances, they fair "moderately well" in 40% of the cases, and poorly in 20%.[10] Predictors of prognosis include the following four categories of factors. Previous medical history, such as prior head injury, pre-traumatic headaches, osteoarthritis. Current symptoms of radicular irritation, radiating numbness or severe neck symptoms. Current psychosocial factors such as long-term problems in adjustment to symptoms of an injury or illness (coping mechanisms), family or job related psychosocial issues, financial problems, and finally, socio-demographic factors to include older age, female gender, less than full-time employment and having dependents.[2,10] These factors taken into consideration are part of the holistic approach to patient care, under the areas of physical, activity and context both personal and environmental as listed in the ICF model (Figure 1) and affect both recovery and sport performance for active individuals.

CASE REPORT

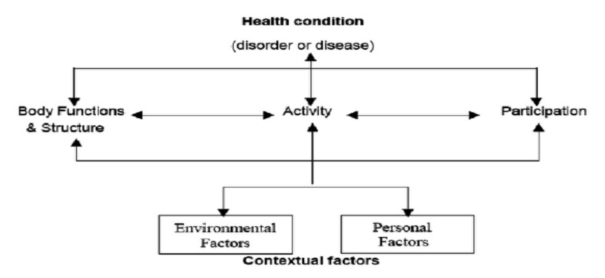
The patient for this case is a professional male athlete at the height of his golf career. Prognosis percentages provided by Cote et al,[9] were unacceptable, however, based upon the predictors provided by the QTF and MVA reports, the prognosis for this individual is good overall. Use of a problem-solving approach within the ICF model provides opportunity to determine a differential diagnosis and plan of care for return to optimum function as quickly as possible and avoidance of chronic sequelae.

This case also presented the opportunity to assess cervical function and the contribution of core stability to performance. Core stabilization is a "buzz word" in gyms and physical therapy facilities across North America and has gained credibility as an intervention in the clinical setting. The transversus abdominus muscle has been identified as a key muscle of the inner core of the trunk,[11] with the longus colli muscle of the anterior cervical region functioning similarly to provide stability to the upper core of the body.[12] There is evidence citing that with neck pain, the deep neck flexors can be weak, with patients demonstrating compensation by using the superficial cervical flexors, such as the sternocleidomastoid (SCM) and anterior scalene muscles. The relevance of the longus colli muscle (LCM) to spinal stability, functional outcome and pain management is often overlooked. Therefore, individuals with WAD must be evaluated for segmental strength and stability. Incorporation of core stability training in rehabilitation to include the often overlooked muscle, the LCM can promote full recovery and enhance performance. Spinal segmental stabilization as initially described focused on training co-contraction of the deep core muscles of the transversus abdominus with the multifidus.[13] More recent recommendations have included the deep core muscles of the cervical region[12] and was applied in this case.

Examination

History and systems review: JD is a 31-year old male professional golfer who was in an MVA, assessed in the Emergency Room and subsequently referred to physical therapy (PT) by his primary care physician (PCP) within 30 hours of the injury. JD was in the passenger seat and though wearing a seatbelt, recalls hitting the right side of his head upon the console of the vehicle but also reports a cracked windshield noted after the collision. He was to begin his off-season training program in the following week to prepare for a competitive season to begin in 2 months. In the emergency room (ER), X-rays were taken and during the out-patient PT assessment,

Figure 1. *International Classification of Functioning, Disability & Health Model*



he reported no symptoms of dizziness, syncope or nausea. The nature of pain was variable with pain level on a 0-10 scale 5/10 at best and 7/10 at worst; aggravated by cervical and UE active range of motion AROM. Though the primary care physician (PCP) prescribed codeine for pain and flexeril for muscle spasm use at night, neither had been used. When asked about the use of NSAIDs, the patient reported taking 4 generic ibuprofen tablets (800 mg total) with each meal.

Medical history: X-rays taken, uncertain of views and no copies available. Negative for hypertension, diabetes mellitus, prior surgeries. Good health per patient report with yearly physicals and checks for skin lesions due to sun exposure when needed. Negative for anxiety or depression treatments--relevant question due to strong pain medications prescribed by doctor of medicine (MD) and prognostic predictor of outcome with WAD. Hairline fracture of lunate metacarpal due to trauma 8 months prior with good healing and no complications.

Social and activity history: Travels and competes in tournaments 38 weeks per year. Resides with parents and maintains physical fitness with aerobic, flexibility, strengthening and core stability components to fitness program.

Tests and Measures

• **Grip dynamometer strength:** Right 110 lbs, 108, 110; Left 105 lbs, 104, 105.

• **Palpation:** Exquisite tenderness along bilateral levator scapulae, erector spinae bilaterally and anterior scalene mm. Increased tissue tension along bilateral upper trapezii mm and SCM.

• **Joint Mobility testing:** Upper cervical stability testing of C1, C2 ligaments of stability (alar, transverse), also assessed for symmetrical motion and presence of crepitus or signs of fracture. Joint stability and mobility findings: No ligamentous stability at alar nor transverse ligaments. At O-A joint: flexion right and sidebent left positions with decreased right rotation at C1-C2; hypomobility noted C5-6 with decreased SB Right noted in extension; elevated 1st rib left, thoracic hypomobility with decreased extension at segments T3-6. No S&S noted or reported with end-range passive rotation right nor left nor sustained position at end range.

• **Functional activities:** Unable to sit/stand for more than 15 minutes due to pain and unable to demonstrate golf swing due to reported "weight of head".

• **Neural:** Positive for adverse neural tension using Upper Limb Tension Test Pattern #1 Median nerve R>>L; all others negative. No symptoms projecting to extremities, intact to light touch and pressure in dermatomal distribution bilaterally. Reflexes normal and equal bilaterally.

• **Patient goals:** Tolerate sustained postures for >1 hour. Return to full golf activities. Decrease pain level.

Evaluation

JD presents with joint dysfunction of the cervical spine with strain of soft tissue due to high velocity deceleration. Testing revealed decreased functional mobility due to limitations in range of motion ROM and strength with pain due to both strained soft tissue and impaired joint mobility with probable local inflammation.

Treatment diagnosis & Prognosis: Diagnosis for this athlete falls within Grade II WAD per clinical practice guidelines. Screening and manual therapy assessment did not denote fracture or medical complications, however, physician contacted to rule out fracture based upon radiological findings. Impaired joint mobility, motor function, muscle performance and range of motion associated with localized inflammation denote need for intervention. Function and mobility status were much greater prior to this acute incident. Patient was appropriate for PT treatment with good prognosis for recovery. Plan of care included treatment 2-3 times per week for 4 weeks (as most) to progress to off-season training regimen. Goals included restoration of full ROM and normal strength with recruitment of deep cervical stabilizers to enhance stability with upright postures.

Intervention

Coordination, communication, cocumentation: Communication with referring physician regarding the results of x-rays (negative) and outcome of MD prescribed MRI (negative) to rule out disk herniation.

Therapeutic Exercise/Functional Training

Week 1: Manual therapy: Soft tissue mobilization to deep anterior cervical mm, pericervical/periscapular musculature; joint oscillations to mid-cervical and muscle energy techniques to correct

Table 1. *Measures taken with inclinometer. Muscle testing (MMT)/ strength testing inhibited by pain.*

Motion/Muscle	AROM	PROM	MMT-right	MMT-left
Cerv.flexion	20 degrees	45 degrees	4/5	
Cerv. Extension	10 degrees	15 degrees	4/5	
Cerv. Rotation	40Right; 30 Left	45Right; 37 Left	4-/5	4-/5
Cerv. SB right	30 degrees	30 degrees	4-/5	4-/5
Cerv. SB left	30 degrees	40 degrees	4/5	4/5
Shldr. Abd	174	175	4/5	4/5
Lower Traps	WNL	WNL	4-/5	4-/5

C1-C2, with manipulation of thoracic T3-T7. **Education:** Resting postures and pain management, use of ice and heat. Athlete had TENS unit and cleared to use as needed. Discontinuance of high-level core training program, continued supported cardiovascular training on recumbent bike. No golf. Met at motion analysis bay to confirm 'no golf" when unable to maintain stance to demonstrate swing. Reviewed training schedule plan and competition plans for 1st quarter of year to demonstrate that rehabilitation time will still allow for time to prepare for season. **Therapeutic exercise:** Initiated activation of deep cervical mm without SCM/ant scalene recruitment taught during 1st visit. In supine, flattening of cervical lordosis indicative of recruitment of LCM. **Isometrics:** Persiscapular musculature in supine with progression to standing with control of cervical compensatory motions. Gentle ANT stretching done for upper extremity.

Week 2: Written results and copies of X-rays and MRI (disk herniation/protrusion to left at C5-6-7) received. No treatment change, with increased education of athlete regarding prognosis. Continued STM to cervical musculature, athlete independent with flexibility and thoracic self-mobilizations. **Restored:** Full Active Rotation and SB in cervical region. Negative ANT. Therapeutic Exercise Progressed with inner core cervical training with sustained holds 10-30 seconds and isometrics to extension (added trunk core in supine with cervical supported postures: mat and ball). Taped in cervical/scapular neutral.

Week 3: Therapeutic exercise: Interval training on recumbent bike, upper extremity ergometer warm-up. Cervical eccentrics in sitting with sustained holds through range; prone unsupported static trunk/scapular stabilization added with cervical alignment emphasized. Neurodevelopment sequence for exercise progression as outlined by Morgan[22] and Commeford and Mottram[23] were followed. Full lower extremity gym program resumed.

Week 4: **Therapeutic exercise:** Supine cervical flexion without compensatory motions, end range perturbation added. Maintenance (1) visit with STM, modality of heat or ice prn and supervision core routine for technique corrections. Noted initiation of superficial muscles prior to deep cervical muscle recruitment with maximal contractions. Requires continued training for safe progression without exacerbation. Continued gym program with limitations, golf putting for 20 minutes, 30 minutes (alternate days). **Restored:** Full muscular strength (5/5) all motions.

Week 5: Gym and core routine without limitations. Assessment cervical recruitment-good. Chipping 20 minutes plus putts 15 minutes every other day. Approved custom pillow for travel. All PT goals met, released by MD. Per athlete request, continued maintenance, 1x per week, for enhancement of performance with fitness/wellness visits and direction with progression of exercise program.

Week 6: Continued maintenance/gym program for strengthening. Progress through clubs-each iron 10 strokes, putt alternate days. Driver used on last day of week.

Week 7: Full session with swing coach: Continued progressive increase through off-season-2 weeks projected prior to competition.

Outcomes

Athlete returned to full competition/golf activities and played a successful year without exacerbation of cervical symptoms.

- Upper extremity strength 5/5, pain level 0/5
- Cervical and upper extremity passive & active ROM WNL
- Cervical joint mobility cleared of dysfunction
- Tolerated static postures and full training regimen w/o pain
- Independent with HEP for cervical stabilization exercise program, with postural correction and appropriate resting postures for cervical comfort.

CONCLUSION

Athlete attained full recovery to perform competitively without complications. Training regimen included high level of core stability training for the cervical and trunk region. This case demonstrates that though low-level evidence has been available to support clinical management guidelines for management of whiplash, clinicians can refer to these guidelines but must continue to rely on application of available evidence and clinical expertise for effective patient recovery.

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Letter to the Editor

The Power of the Statistical Test

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To the Editor,

I would like to add some reflections about Steele's paper published in 2012.[1] I could notice two main points in that paper. One of these is about the scientific language to communicate conclusions to policy makers and the other one is about the statistics decision theory. These problems are consequence of R. Fisher's tradition to test the null hypothesis through the arbitrary cut with α in 0.05, 0.01 or 0.001.

One good example about the problem with scientific language translation happened during the O.J. Simpson trial. A scientist called to give evidence about blood samples declared that there was one chance in 10 millions (0.5% of population) that O.J. was not the murderer. This specialist must be told there were 2.5 millions chance in one that O.J. was the real murderer. Therefore, Simpson's defensor convinced the jury members there was one chance that O.J. was not guilty, then the jury decided upon acquittal.[2]

As for statistics decision, the failure in rejecting the null hypothesis, when it is not true, is an important error that can be controlled by β. Moreover, in some sciences, like in climate changes, it should be morally more important to test alternative hypothesis than to do the statistical decision based on the null hypothesis tests. This is an intuitive conclusion supported by the probable worse consequences to conclude the world temperature will not rise if it is false (type II error). The power of statistical test is estimated by 1-β, and we can call this effect of size (ES). Apart from this problem, several scientific journal reviewers confounded the significance of the statistic tests with the experimental significance (or sig = $1\text{-}0.95^{\text{n. comparisons}}$). Thereby, they have been approving for publication papers with low experimental power. For instance, Lancha Jr et al,[3] concluded that it is possible to increase the speed of rats' asparte-malate shuttle through aspartate, asparagine and carnitine supplementation. But they used t-test to compare 48 averages and; because of this, the study's α got worse from 0.05 to 0.708. Moreover, ES has a intrinsic value judgment to test alternative hypothesis. Like Pearson's correlation coefficient, that we can tell if it is perfect, excellent, good or reasonable, the ES is low (or ≤0.2), moderate (≈0.5) and high (or ≥0.8).[4] That could help the scientist use a more comprehensible language to policy makers and does a little value judgment without exposing himself using no statistical or scientific language. Of course this strategy cannot solve the problem, but this can reduce the bad consequences. Like Cohen advised, the right statistical decision is supported by the α significance criterion, the sample size, the population effect size, and the power of the test.[4]

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