Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Medicine and Health Sciences
Department of Neuromedicine and Movement Science

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In-Season Training Load Quantification in a Professional Male Football Team: Starters Versus Nonstarters

Master's thesis in Physical Activity and Health - Exercise Physiology
Supervisor: Ulrik Wisløff
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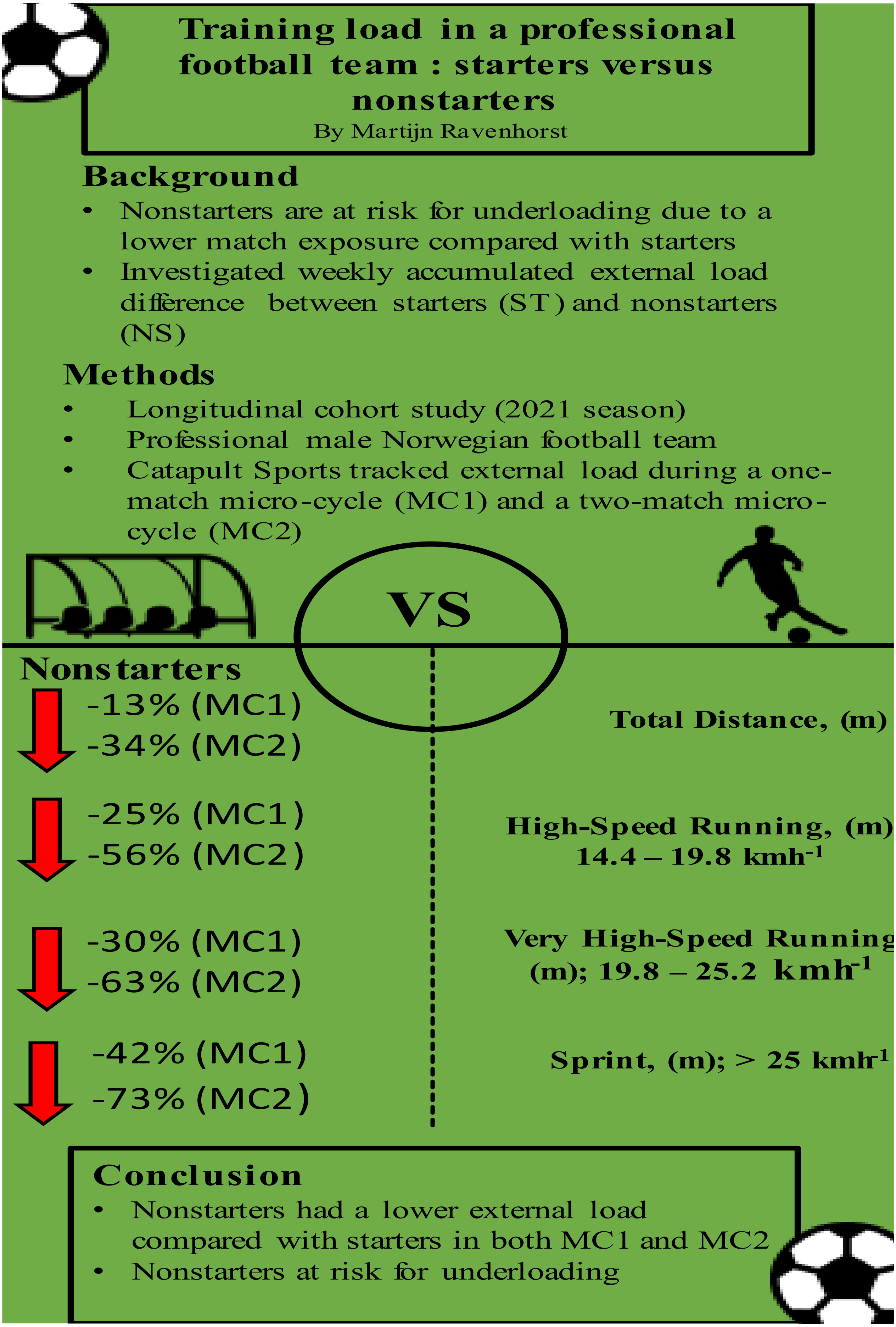
Infographic



Abstract

Purpose: The aim of this study was to quantify and compare accumulated field time and external load of starters and nonstarters in a micro—cycle with one match and two matches. ***Methods:*** Twenty-five professional male football players (24.8 ± 5.0 years, 184.3 ± 5.8 cm, 80.2 ± 7.6 kg) participated in this study. They were categorised based on starting status and divided into starters and nonstarters. Accumulated field time (FT) and external load variables; total distance (TD), high-speed running distance (HSR: 14.4 – 19.8 $km \cdot h^{-1}$), very high-speed running (VHSR: 19.8 – 25.2 $km \cdot h^{-1}$), sprint (SPR: > 25.2 $km \cdot h^{-1}$), and accelerations (ACC: > 2 $m \cdot s^{-2}$), were monitored using a combined 10Hz Global navigation satellite system (GNSS)/Local positioning system (LPS). The accumulated field time and external load difference between starters and nonstarters in a micro-cycle with one match (n=6 micro-cycles) and a micro-cycle with two matches (n=7 micro-cycles) were calculated and compared using a linear mixed model. ***Results:*** In a micro-cycle with one match, nonstarters had significantly less FT (−8%, Hedges' g effect size [g] = 0.95), TD (−13%, g = 1.07), HSR (−25%, g = 1.09), VHSR (−30%, g = 0.78), SPR (−42%, g = 0.71), and ACC (−21%, g = 0.92) compared to starters. Furthermore, nonstarters had significantly less FT (−22%, g = 2.41), TD (−34%, g = 3.33), HSR (−56%, g = 2.52), VHSR (−63%, g = 1.83), SPR (−73%, g = 0.97), and ACC (−35%, g = 1.72) than starters in a micro-cycle with two matches. ***Conclusion:*** Nonstarters had a significantly lower accumulated field time and external load compared to starters in both a micro-cycle with one match and a micro-cycle with two matches. Nonstarters are at risk of being underloaded, and appropriate compensatory strategies are needed.

Keywords: GPS, external load, starters, nonstarters, periodization

List of Abbreviations

ACC = Accelerations

FT = Field time

F = Fringe player

GNSS =Global navigation satellite system

GPS = Global positioning system

HSR = High-speed running

LPS = Local position system

MC1 = One-match micro-cycle

MC2 = Two-match micro-cycle

NS = Nonstarter

SPR = Sprint

ST = Starter

TD = Total distance

VHSR = Very high-speed running

1. Introduction

A football match has an intermittent aerobic and anaerobic nature with periods of high and low intensity activities, and a variety of high and low intensity multidirectional movements (Bangsbo, 1994; Mohr, Krustrup, & Bangsbo, 2003). The distance and intensity of the match are dependent on the physical performance, quality of the opponent (Rampini et al., 2007), and fitness levels (Helgerud et al., 2001). Match demands have increased significantly during the last years as can be seen in the English Premier League and Spanish LaLiga where the high-intensity demands (>19.8 $km \cdot h^{-1}$) increased with up to 35% (Barnes et al., 2014; Lago-Peñas et al., 2022). The training sessions prior to a match have the objective to prepare the players optimally for the physiological challenges during match play. Each training session within a week has their own physical emphasis (e.g., strength, endurance, speed, activation) and practitioners manipulate parts of the training session to reach certain physical goals. However, every week and every training session is different in terms of training load (lower or higher) depending on the physical needs (e.g., did not reach physical goal set by the practitioner) and restrictions (e.g., injuries) of the team and the individual.

Training load can be seen as a combination of external and internal load, where the external load can be defined as the physical work of the prescribed training (e.g., total distance, sprinting distance, number of accelerations) and the internal load as the physiological response (e.g., heart rate, blood lactate) to the physical work performed (Impellizzeri et al., 2004; Impellizzeri et al., 2005). Impellizzeri, Marcora, & Couts (2019) recommend using internal load as a primary measure when monitoring athletes, since it is the internal load that determines the training outcome. However, the focus of training load monitoring shifted over the years towards primarily monitoring external load with the advent of more accurate global positioning systems (GPS). Overall, training load monitoring is a widely adopted practice by many elite football clubs with the purpose to objectively quantify and manage day-to-day and accumulated training load on both a team and an individual basis (Akenhead & Nassis, 2016; Halson, 2014). An individual approach is of importance due to the position specific demands during a match (Baptista et al., 2018; Bradley et al., 2009; Di Salvo et al., 2007; Ingebrigtsen et al., 2015) and the difference in how athletes respond to a similar training load (e.g., low-responders versus high-responders, young versus old, low fitness versus high fitness levels, genetics) (Halson, 2014; Impellizzeri, Marcora, & Coutts, 2019).

Most elite football teams use a micro-cycle structure, with the match as reference and using a "match-day minus system" introduced by Malone et al., (2005), to structure their training and training load. During a typical micro-cycle with one match at the end of the week, a higher training load can be found early in the week with a progressive reduction in load closer to the match (Akenhead, Harley, & Tweddle, 2016; Chena et al., 2021; Martín-García et al., 2018). However, nowadays most football teams play multiple matches during a micro-cycle due to participation in multiple competitions throughout a season. Teams would sometimes have to play multiple matches per week for a prolonged period (e.g., 6 matches in three weeks) which we can refer to as a congested period (Carling, Le Gall, & Dupont, 2012). It has been shown that the physical performance during a match and overall team performance is not affected during these congested periods (Bengtsson, Ekstrand, & Hägglund, 2013; Dupont et al., 2010; Dellal et al., 2015). However, a higher injury rate (Dupont et al., 2010) and increased muscle injury risk injury risk (Bengtsson, Ekstrand, & Hägglund, 2013) has been found during congested periods with a low recovery time (i.e., <96 hours) between matches. Dellal et al. (2015) suggested that a higher match exposure during a congested period could be a possible explanation for the increased injury rate. Furthermore, it has been found that basal salivary immunoglobulin A (inflammatory marker), plasma testosterone (hormonal marker), psychological factors (Profile of Mood State questionnaire), and physical tests (e.g., Yo-Yo intermittent recovery test level 1, squat jump, repeated shuttle sprint ability test) are negatively affected during congested periods (Morgans et al., 2014; Saidi et al., 2020; Saidi et al., 2022). In addition, Ispirlidis et al. (2008) found that physical performance tests (e.g., vertical jump height, maximal squat strength, 20-m sprint), muscle damage markers (e.g., creatine kinase, lactate dehydrogenase), inflammatory markers (e.g., leukocyte count, C-reactive protein), and oxidative stress markers (e.g., uric acid, thiobarbituric acid-reactive substances) are negatively affected in elite male football players for up to 72 hours post-match. It thus seems that 72 and 96 hours between matches are needed to ensure recovery for the next match.

Most substitutions during a football match occur at half-time (after 45 minutes) and between the 60^{th} – 85^{th} minute (Bradley, Lago-Peñas, & Rey, 2014; Gomez, Lago-Penãs, & Owen, 2016), and coaches attempt to use substitutes to reduce match-induced fatigue in the team (Mohr et al., 2003) or change tactics (Lorenzo Martínez et al., 2020). Due to substitutions made during a match, differences in match exposure can be found within a football team with regular starters having a higher match exposure than nonstarters. This might result in a difference in physical fitness within a team over time as an association between match exposure and physical performance has been found (Silva et al., 2011). A lower match-exposure for nonstarters might indeed result in reduced physical fitness since previous research has found that the match serves as the greatest physical stimuli in a micro-cycle (Anderson et al., 2016b; Morgans, Di Michele, & Drust, 2018). Nonstarters having a lower match-exposure puts them at risk of being underloaded and managing training load is thus of high importance to reduce any potential differences between starters and nonstarters. Most elite football clubs plan a compensatory session for nonstarters the day after the match with the goal of eliciting a similar physical stimulus as a match. Nevertheless, numerous studies have found training load differences between starters and nonstarters during multiple periods in-season; a full season (Anderson et al., 2016a), six-weeks (Oliveira et al., 2021), and micro-cycles (Anderson et al., 2016b, Casamichana et al., 2022; Stevens et al., 2017). However, few studies have investigated the in-season external load difference between starters and nonstarters during a micro-cycle with two matches. Therefore, the aim of this study was to quantify and compare the accumulated field time and external load of starters and nonstarters in a micro-cycle with one match and two matches. We hypothesized that nonstarters would have a significant lower external load compared starters during both a micro-cycle with one match and two matches, and therefore providing practical applications to plan appropriate compensation sessions for nonstarters.

2. Methods

2.1 Participants

Twenty-five outfield players (mean ± SD: 24.8 ± 5.0 years, 184.3 ± 5.8 cm, 80.2 ± 7.6 kg) from a professional male football team playing in the Norwegian elite league participated in this study. The team took part in three competitions during this study (Eliteserien, Norgesmesterskapet, and EUFA Europa Conference League qualifications) and played all included micro-cycles in a variation of a 4−3−3 formation. Goalkeepers were excluded from the sample during this study. This study was conducted according to the Declaration of Helsinki and all subjects gave their written informed consent prior to participation in the study.

2.2 Design

For this longitudinal cohort study during the 2021 season, training and match data were collected using a combined Global navigation satellite system (GNSS) (Catapult Sports, Melbourne, Australia) and Local positioning system (LPS) (Catapult ClearSky, Melbourne, Australia). Thirteen micro-cycles (six micro-cycles with one match and 7 micro-cycles with two matches) followed an adequate structure and were included for analysis. For a one-match micro-cycle (MC1), four training sessions, one match, and one compensatory session for nonstarters were included (see Table 1 for the micro-cycle structure). For a two-match micro-cycle (MC2), two training sessions, two matches, and two compensatory sessions for nonstarters were included (see Table 2 for the micro-cycle structure). The compensatory session for nonstarters was either a group training session or participation in a second team match. The coaching staff determined which type of compensatory session was done per micro-cycle and decided the playing time for each player in the case of a second team match being chosen as compensatory session.

Table 1. Structure of a micro-cycle with one match according to the "match-day minus" system introduced by Malone et al., (2005).

Micro-cycle:	Training session	Training session	Training session	Training session	Match	Compensatory session
MC1 (= 6)	MD−4	MD−3	MD−2	MD−1	MD	MD+1

Table 2. Structure of a micro-cycle with two matches according to the "match-day minus" system introduced by Malone et al., (2005).

Micro-cycle:	Training session	Match	Compensatory session	Training session	Match	Compensatory session
MC2 (= 7)	MD−1	MD	MD+1	MD−1	MD	MD+1

The players were categorised according to their starting status and divided into three groups (starters, nonstarters, or fringe players) based on whether the player started the match or not, and the number of minutes played during the match (see Table 3 for the number of observations per starting status group in each micro-cycle type). The assessment of starting status group was done per micro-cycle and players could thus be assigned in a different starting status group across but not within micro-cycles. The inclusion criteria for assigning players to a starting status group during a one-match micro-cycle were based on previous research (Nobari et al., 2021) and slightly adjusted for a two-match micro-cycle. During a one-match micro-cycle players were assigned as following: (1) starter if a player started the match and played > 60 minutes, (2) nonstarter if a player played < 60 minutes. During a two-match micro-cycle, players were defined as following: (1) starter if a player started both matches and played > 60 minutes in both matches, (2) nonstarter if a player played < 60 minutes in both matches, (3) fringe player if a player started one match and played > 60 minutes in that same match and played < 60 minutes in the other match.

Table 3. Number of included observations per starting status group in each micro-cycle type.

Micro-Cycle	**Starters**	**Nonstarters**	**Fringe players**	**Total**
MC1	34 (n = 15)	30 (n = 17)	0	64 (n = 22)
MC2	33 (n = 15)	20 (n = 14)	19 (n = 10)	72 (n = 23)

Note. Data presented as number of observations with the number of subjects in brackets. MC1: one-match micro-cycle, MC2: two-match micro-cycle.

2.21 Inclusion Criteria Data

For the data to be included in a micro-cycle, a player had to participate in all training sessions prior to the match and finish all full training sessions. In a one-match micro-cycle this meant that a player had to participate in the training sessions MD−4 until MD−1 (see Table 1) and in a two-match micro-cycle a player had to participate in both training sessions MD−1 (see Table 2).

2.22 Exclusion Criteria Data

All individual sessions, rehab sessions, indoor sessions were excluded from this study. A player that did not participate in all training sessions before the match (see inclusion criteria) or did not finish all training sessions, was excluded from that specific micro-cycle.

2.3 Data Collection and Analysis

During both training sessions and matches, players wore a vest with a 10 Hz GNSS/LPS tracking unit placed on the upper back (Catapult Vector S7, 81mm x 43mm x 16mm, Figure 1). Previous research has shown that this type of tracking system provides valid and reliable estimates of constant and instantaneous velocities for both linear and multidirectional movement (Castellano et al., 2011; Varley, Fairweather, & Aughey, 2012). The data recorded by the units were downloaded after each session for further analysis using Catapult Openfield Cloud Analytics (OpenField 3.3.1 Build #68050). The following variables were selected for analysis during this study: field time defined as the time spent on the field (FT; min), total distance (TD; m), distance in high-speed running defined as a running speed between 14.4 – 19.8 $km \cdot h^{-1}$ (HSR; m), very high speed running defined as 19.8 – 25.2 $km \cdot h^{-1}$ (VHSR; m), sprint defined as >25.2 $km \cdot h^{-1}$ (SPR; m), and acceleration efforts defined as > 2 $m \cdot s^{-2}$ (ACC; no.). The velocity thresholds chosen are in accordance with previous research (Bradley et al., 2009; Di Salvo et al., 2007; Rampini et al., 2007).

Figure 1. Catapult sports vector S7 physical features. Source: https://support.catapultsports.com/hc/en-us/articles/360000919456-Vector-S7-G7-Overview

The criteria for acceleration efforts were chosen as by default in Catapult Sports and were as following: (1) the acceleration reaches a minimum of 2 $m \cdot s^{-2}$, (2) the player must stay above this minimum threshold for 0.6 seconds to be counted, (3) the player must leave the acceleration band for a duration of the timeout window (1 seconds) before the player can reach another effort.

The accumulated field time and external load (TD, HSR, VHSR, SPR, and ACC) for the two types of micro-cycles (MC1 and MC2) were calculated by summing up all the main training sessions, matches, and compensatory sessions. The field time and external load variables during the micro-cycle were expressed in absolute values. Internal load variables were not included in this study due to low adherence of the players wearing the vest with integrated ECG technology on the skin as necessary.

2.4 Statistical Analysis

A linear mixed model with subject ID as random factor, starting status as fixed factor, and field time and external load variables as dependent variables, was used to compare the starting status groups in the two types of micro-cycles and analyse the differences between the groups. The data output was organised by micro-cycle. The linear mixed model was used to adjust for repeated measurements. Hedges' g effect size and 95% confidence interval were calculated to display the magnitude of the differences found. The Hopkins' thresholds for effect size were used: ≤0.2, trivial; >0.2, small; >0.6, moderate; >1.2, large; >2.0, very large; and >4.0, nearly perfect (Hopkins et al., 2009). Data was presented as mean ± standard deviation and effect size with a 95% confidence interval lower and upper limit. The level of significance was set to P <.05. The statistical procedures were performed in SPSS version 27.0 for Windows (SPSS inc., Chicago IL, USA).

3. Results

3.1 One-match Micro-cycle

Nonstarters had a significantly lower accumulated field time and external load compared to starters during a one-match micro-cycle, as shown in Table 4.

Nonstarters had significantly less FT (−8%) compared to starters. Furthermore, nonstarters covered significantly less TD (−13%), HSR (−25%), VHSR (−30%), SPR (−42%), and ACC (−21%) than starters.

Table 4. Comparison of accumulated field time and external load between starters (ST) and nonstarters (NS) in a one-match micro-cycle.

Comparison	**Variable**	**ST, mean ± SD**	**NS, mean ± SD**	***P*-value**	**ES (LL – UL)**	**Classification**
ST – NS	FT, min	369 ± 20	338 ± 42	<.001	0.95 (0.48 – 1.45)	Moderate
	TD, m	30458 ± 2832	26628 ± 4447	<.001	1.07 (0.57 – 1.57)	Moderate
	HSR, m	3438 ± 596	2585 ± 1074	<.001	1.09 (0.63 – 1.56)	Moderate
	VHSR, m	1187 ± 389	826 ± 457	.004	0.78 (0.26 – 1.29)	Moderate
	SPR, m	337 ± 199	194 ± 186	.008	0.71 (0.20 – 1.22)	Moderate
	ACC, no.	373 ± 66	296 ± 87	<.001	0.92 (0.48 – 1.35)	Moderate

Note. ST: starters, NS: nonstarters, FT; field time, TD: total distance, HSR: high-speed running (14.4 – 19.8 $km \cdot h^{-1}$), VHSR: very high-speed running (19.8 – 25.2 $km \cdot h^{-1}$), SPR: sprint (> 25.2 $km \cdot h^{-1}$), ACC: accelerations (> 2 $m \cdot s^{-2}$), ES: Hedges' g effect size, LL: 95% confidence interval lower limit, UL: 95% confidence interval upper limit.

3.2 Two-match Micro-cycle

The mean and standard deviation of each variable for every starting status group is shown in Table 5. Table 5 and 6 show that nonstarters had a significantly lower accumulated field time and external load compared to starters and fringe players during a two-match micro-cycle. Furthermore, fringe players had a significantly lower accumulated field time and external load compared to starters except for sprint distance, which was lower but not significant.

Nonstarters had significantly less FT compared to both starters (−22%) and fringe players (−13%). Furthermore, nonstarters covered less TD (−34% vs starters, −19% vs fringe players), HSR (−56% vs starters, −38% vs fringe players), VHSR (−63% vs starters, −41% vs fringe players), SPR (−73% vs starters, −61% vs fringe players), and ACC (−35% vs starters, −23% vs fringe players) compared to both starters and fringe players.

In addition, fringe players had significantly less FT (−10%) compared to starters. Fringe players also covered significantly less TD (−19%), HSR (−29%), VHSR (−38%), ACC (−15%) than to starters. Although not significant, fringe players covered less SPR (−32%) compared to starters.

Table 5. Quantification (mean ± SD) of accumulated field time and external load variables in a two-match micro-cycle for starters (ST), fringe players (F), and nonstarters (NS).

Variable	ST, mean ± SD	F, mean ± SD	NS, mean ± SD
FT, min	293 ± 17	262 ± 25	229 ± 38
TD, m	26763 ± 2397	21780 ± 2478	17696 ± 3219
HSR, m	3192 ± 743	2254 ± 628	1406 ± 621
VHSR, m	1113 ± 440	695 ± 298	413 ± 200
SPR, m	295 ± 178	200 ± 133	78 ± 60
ACC, no.	284 ± 56	240 ± 54	185 ± 44

Note. ST: starters, NS: nonstarters, F: fringe players, FT; field time, TD: total distance, HSR: high-speed running (14.4 – 19.8 $km \cdot h^{-1}$), VHSR: very high-speed running (19.8 – 25.2 $km \cdot h^{-1}$), SPR: sprint (> 25.2 $km \cdot h^{-1}$), ACC: accelerations (> 2 $m \cdot s^{-2}$), SD: standard deviation.

Table 6. Comparison of accumulated field time and external load variables between starters (ST), fringe players (F), and nonstarters (NS) in a two-match micro-cycle.

Comparison	Variable	*P*-value	ES (LL – UL)	Classification
ST – NS	FT, min	<.001	2.41 (1.85 – 2.98)	Very large
	TD, m	<.001	3.33 (2.75 – 3.91)	Very large
	HSR, m	<.001	2.52 (1.97 – 3.06)	Very large
	VHSR, m	<.001	1.83 (1.33 – 2.33)	Large
	SPR, m	<.001	0.97 (0.51 – 1.42)	Moderate
	ACC, no.	<.001	1.72 (1.19 – 2.25)	Large
ST – F	FT, min	<.001	1.15 (0.57 – 1.72)	Moderate
	TD, m	<.001	1.79 (1.21 – 2.38)	Large
	HSR, m	<.001	1.35 (0.81 – 1.89)	Large
	VHSR, m	<.001	1.03 (0.55 – 1.52)	Moderate
	SPR, m	.716	0.08 (−0.36 – 0.52)	Trivial
	ACC, no.	.026	0.60 (0.07 – 1.13)	Small
F – NS	FT, min	<.001	1.21 (0.60 – 1.82)	Large
	TD, m	<.001	1.46 (0.87 – 2.06)	Large
	HSR, m	<.001	1.11 (0.59 – 1.63)	Moderate
	VHSR, m	.001	0.76 (0.31 – 1.21)	Moderate
	SPR, m	<.001	0.84 (0.43 – 1.26)	Moderate
	ACC, no.	<.001	1.06 (0.56 – 1.56)	Moderate

Note. ST: starters, NS: nonstarters, F: fringe players, FT: field time, TD: total distance, HSR: high-speed running (14.4 – 19.8 $km \cdot h^{-1}$), VHSR: very high-speed running (19.8 – 25.2 $km \cdot h^{-1}$), SPR: sprint (> 25.2 $km \cdot h^{-1}$), ACC: accelerations (> 2 $m \cdot s^{-2}$), ES: Hedges' g effect size, LL: 95% confidence interval lower limit, UL: 95% confidence interval upper limit.

4. Discussion

To the authors knowledge, this it one of the first studies to quantify and compare accumulated external load for starters and nonstarters during in-season micro-cycles with both one and two matches. In line with our hypothesis, nonstarters had a significantly lower accumulated field time and covered less TD, HSR, VHSR, SPR, and ACC compared to starters in a micro-cycle with one match and a micro-cycle with two matches. Importantly, this study observed significant differences in external load between starters and nonstarters, and thus having implication for potential compensatory strategies that should be used during in-season micro-cycles to impose an appropriate physical stimulus for nonstarters.

One-match Micro-cycle

In line with previous studies (Anderson et al., 2016b; Casamichana et al., 2022; Chena et al., 2021; Stevens et al., 2017), we found that nonstarters had a lower accumulated external load compared to starters. In our study, the mean accumulated external load observed for starters (TD, ~30.5km: HSR, ~3500m; VHSR, ~1190m; SPR, ~335m) is similar to the external load ranges (TD, 26.9 – 31.9 km; VHSR, 843 – 1472 m; SPR, 171 – 476m) found in a study conducted with a reserve squad of a Spanish LaLiga team (Casamichana et al., 2022). However, our findings are higher compared to reported external load (TD, ~25 – 27.5 km; HSR, ~2500m; VHSR, ~860m; SPR, ~300m) by previous studies from the English Premier League and Spanish LaLiga (Anderson et al., 2016b; Chena et al., 2021). The differences in the accumulated external load between our study and the studies of the English Premier League and Spanish LaLiga are hard to explain since our study followed a similar micro-cycle structure. Furthermore, the field time difference between our study and the study of Anderson et al. (2016b) is minimal with seventeen minutes (~369min our study vs ~352min Anderson et al. 2016b). In addition, nonstarters from our study had a similar observed external load (TD, ~26.6km; HSR, ~2600m, VHSR, ~830m; SPR, ~195m) compared to the starters of the study from Anderson et al., with only SPR begin considerably lower in our study which could be explained by the lower match exposure for nonstarters compared to starters. It is thus likely that the differences in accumulated load for starters between our study and the studies of the English Premier League and Spanish LaLiga are due to different periodization of the training week. For example, the study Anderson et al. had a clear physical periodization with MD-4 and MD-3 being significantly higher than MD-2 and MD-1. However, this statement remains speculative as our study did not provide any information on day-to-day variation in external load.

In our study, nonstarters had 8% less field time and covered 13% less TD, 25% less distance in HSR, 30% in VHSR, 42% in SPR, and 21% ACC compared with starters. This is in line with the study of Stevens et al., (2017), where they found a 31% difference in HSR and 29% difference in VHSR between starters and nonstarters. The accumulated field time difference between the two groups (369 min starters vs 338 min nonstarters) is due to the lower match exposure for nonstarters, but it is unlikely that this is the only explanation for the differences in external load compared with starters. Even in a hypothetical case where the nonstarters of this study played an additional thirty-one minutes with the mean match demands (VHSR, 8.3 $m \cdot min^{-1}$; SPR, 1.7 $m \cdot min^{-1}$) found by Dalen et al. (2021) in an elite Norwegian team, nonstarters would still have had a lower accumulated external load compared to starters. It thus seems that the compensatory session for nonstarters in this study did not impose the same physical demands, especially for HSR, VHSR, and SPR, as during a match and consequently leaving nonstarters at risk of being underloaded.

Two-match Micro-cycle

The external load for starters observed during our study (TD, ~27km; HSR, ~3200m; VHSR, ~1100m; SPR, 295m) was lower compared to a previous study (TD, ~32km; HSR, ~4200m; VHSR, ~1480m; SPR, ~520m) from the English Premier League (Anderson et al., 2016b). However, a two-match micro-cycle in the study of Anderson et al. had four training sessions compared to two training session during our study and consequently the field time was higher (~295 min in our study vs ~405 min Anderson et al. study) compared to our study. This explains why the study of Anderson et al. observed a higher external load compared to our study.

In this study, we found that nonstarters had 22% less field time and covered 34% less TD, 56% less HSR, 63% VHSR, 73% SPR, and 35% less ACC compared to starters. We thus found a greater difference between starters and nonstarters than during a one-match micro-cycle. This is in line with findings of a previous study where they found a greater external load difference between starters and nonstarters in a micro-cycle with two matches compared to micro-cycle with one match (Stevens et al., 2017). The greater difference between starters and nonstarters is likely due to the lower match exposure of nonstarters and the match being the main determinant of physical stimuli during the micro-cycle. Moreover, the field time difference between starters and nonstarters is higher in a two-match micro-cycle (MC2 64 min vs MC1 31 min) which could have contributed to the greater external load difference in a two-match micro-cycle. Fringe players had a smaller difference compared to starters than nonstarters for all external load variables; TD (−34% nonstarters vs −19% fringe players), HSR (−56% nonstarters vs −29% fringe players), VHSR (−63% nonstarters vs −38% fringe players), SPR (−73% nonstarters vs −32% fringe players), and ACC (−35% nonstarters vs −15% fringe players). The reduction in external load differences for fringe players is likely due to a higher match exposure and the nature of the physical stimuli during the match. Furthermore, the field time difference was lower for fringe players compared to nonstarters (−22% nonstarters vs −10% fringe players) which is due to a match (~90 min) having a longer duration than most compensation sessions (although not presented, ~65 min in this study). Nonstarters would benefit from playing a match as a compensatory strategy, but time restrictions and recovery time need to be taken into consideration. Practitioners must thus be time-efficient during the compensation session and most likely need to prioritize certain physical aspects over others. However, in this study it seems that the compensatory sessions during a two-match micro-cycle did not impose an external stimulus close to match demands and did not result in closing the external load gap between starters and nonstarters.

Previous research found that there is at least 72 hours recovery time needed for inflammatory markers to return to baseline (ispirlidis et al., 2008) and between 72 to 96 hours to maintain match-related physical performance (Dupont et al., 2010). Planning a compensatory session one day after the first game in a two-match micro-cycle would thus mean that nonstarters in this study had insufficient recovery time before the next game which is associated with an increased fatigue-related injury rate and risk (Bengtsson, Ekstrand & Hägglund, 2013; Dupont et al., 2010), however injury rate was not investigated in this study. Most elite football teams struggle with the same problem of nonstarters having a compensatory session one or sometimes two days after the match. One solution would be to plan the compensation session for nonstarters directly after the game, however complications might occur while playing an away game due to traveling plans and/or permission to stay on the pitch after the game. Up until today, medical, and coaching staffs are facing the challenge of players within a team having different training cycles and loading periodization towards the next game due to the differences in match exposure, and there does not seem to be an evidence-based solution found yet.

General

Comparing ACC between studies and within a team has been a debated topic with previous research (Akenhead et al., 2014; Bucheit et al., 2014) having found compromised accuracy for high accelerations (> 4 $m \cdot s^{-2}$) and a high between-unit variability for accelerations (up to 43%) and decelerations (up to 56%) with some GPS-units registering between 2 to 6 times more than others using the same protocol (Bucheit et al., 2014). Therefore, we decided not to compare our ACC results to previous research and practitioners should be careful interpreting our results regarding the ACC difference between starters and nonstarters. To sum up some general findings regarding ACC that have implications for starters and nonstarters, Stevens et al. (2017) found that starters had more medium (1.5 – 3.0 $m \cdot s^{-2}$) and high ACC (> 3 $m \cdot s^{-2}$) compared to nonstarters. Furthermore, Dalen et al. (2021) found that players during 4 vs 4 small-sided games (SSG) had more ACC (> 2 $m \cdot s^{-2}$) per minute than during one-minute peak match demands. SSGs thus seem to be an effective exercise to overload ACC during the compensatory session for nonstarters.

High intensity running (> 19.8 $km \cdot h^{-1}$) has become more important recent years as seen in an increase in distance VHSR and SPR during a match, and it has been shown that a match contributes the most to accumulated high intensity distance during a micro-cycle (Anderson et al., 2016b). It has been found by several studies mentioned earlier and our study that nonstarters have a lower accumulated load in high intensity running, mainly due to the lower match-exposure, and are thus at risk of being underloaded. Structural underloading nonstarters could have a negative effect on physical fitness with a possible reduction in chronic adaptations, and the physical fitness of a player being compromised as a result (Mujika & Padilla, 2000). Furthermore, given the high physical demands of a match, a change in match exposure for nonstarters could result in a sudden change of external load, which has been associated with a higher risk of noncontact muscle injuries (Gabbet, 2004; Gabbet, 2016). It is thus of importance for nonstarters to be exposed to similar physical stimuli as during match-play, especially high intensity running, to maintain physical fitness and readiness to play, and reduce the risk of injury. SSGs' are used by many clubs as an exercise during a compensatory session to elicit a similar physiological stimulus (e.g., minutes spent >90 max heart rate, high ACC per minute) as during a match. However, SSG produce a significantly lower high intensity distance compared to mean and peak match performance (Dalen et al., 2021) and additional top-ups with high intensity runs are thus needed to compensate for the accumulated difference in between starters and nonstarters. Bucheit showed in a report (2019) that high-intensity interval supplementation is an effective method for maintaining the high intensity load in periods of low match exposure, but that tailoring according to individual demand is of importance to meet all physical needs.

Limitations

Despite this study being one of the first to describe accumulated field time and external load differences between starters and nonstarters in a two-match micro-cycle and reflecting a real-world scenario and having practical applications for practitioners, it is not without limitations. First, due to only have studied one team and a small sample size for each starting status group, generalizing the results of this study is not recommended. Furthermore, there was no inclusion criteria specifically for nonstarters (i.e., participation in the compensatory sessions), with as a result that some nonstarters did not participate in all compensatory sessions. Lastly, nonstarters participated in one of two types of compensatory sessions (training session or second team match) which could have had different loading patterns resulting in different external load periodization across nonstarters. However, the last two limitations reflect real-world scenarios where the coaching staff might choose to leave a player out a compensatory session due to training load management and choose a second team match over a training session as a compensatory session to give a player match exposure and strengthen the second team.

5. Conclusion

In summary, nonstarters had a lower accumulated field time and external load compared to starters in both a micro-cycle with one match and two matches. This study demonstrates the need for effective compensation strategies for nonstarters that reduce the external load difference with starters while maintaining physical fitness, not comprising readiness to play, or increasing injury risk. Future studies should further investigate the training load difference between starters and nonstarters by exploring any potential position specific differences and seek for effective methods to reduce the external load differences between starters and nonstarters.

Practical applications

Knowledge about any field time and external load differences within a football team is of great importance for practitioners, particularly when choosing appropriate compensatory strategies for nonstarters. The external load differences, especially found in high intensity distance, that arise based on starting status should be considered of importance and practitioners should plan their compensatory session accordingly to maintain physical fitness for nonstarters while not compromising the readiness to play the next match. When possible, high intensity runs directly after the match are recommended to increase the recovery time afterwards. If this is not possible, recovery time to the next match should be taken into consideration when planning the compensatory session.

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Appendix 1: Vector/Vicon Concurrent Validity Preview

VECTOR / VICON

CONCURRENT VALIDITY PREVIEW

VECTOR CONCURRENT VALIDITY

CATAPULT PREVIEW

PURPOSE

- The following slides are a **preview** of the current analysis taking place for the concurrent validity of Vector against a gold standard motion capture system (Vicon – Nexus)

Please note this is a part of Catapult' Vector internal validation works and all data has been processed by catapult staff.

METHODS

- Data collection took place at night under optimal and consistent lighting conditions
- Four Vector devices were chosen at random from a population of 24 and were placed in the middle of the testing area for 15 minutes prior to data collection
- Catapult Clearsky 2.0 was set up around the testing area with 21 anchors.
- A 20 camera Vicon system was set up (outdoors) with a total capture area of 20m x 15m. The Vicon system was calibrated and operated by experienced staff from the Victoria University biomechanics lab.
- Reflective markers were placed on each shoulder and the assigned device of each participant for data capture.
- Participants completed the following trials:
  - 5m Sprint [3]
  - 10m Sprint [3]
  - 20m Sprint [3]
  - 45 deg change of direction [3]
  - 90 deg change of direction [3]
  - Sport simulation [3]

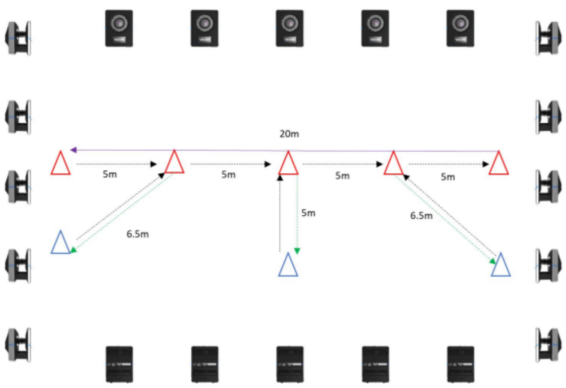


Fig 1 – Vicon camera layout and and trial setup within testing area.

DATA INTEGRITY | VECTOR

VECTOR CONCURRENT VALIDITY

DATA ANALYSIS

- Vicon data down sampled from 250 Hz to 10 Hz (the sampling frequency of Vector technology) in accordance with previous studies [1]
- Vicon data was appropriately filtered to ensure the removal of the effects of centre of mass displacement during locomotion, as this is not present in Catapult data.
- Each trial was isolated within the respective GPS and LPS 10Hz data exports from the OpenField software (ver 2.0)
- Data was processed within R [3.0.6] statistical computing software and initial comparisons made using a cross correlation methodology, from which the following graphs were prepared.

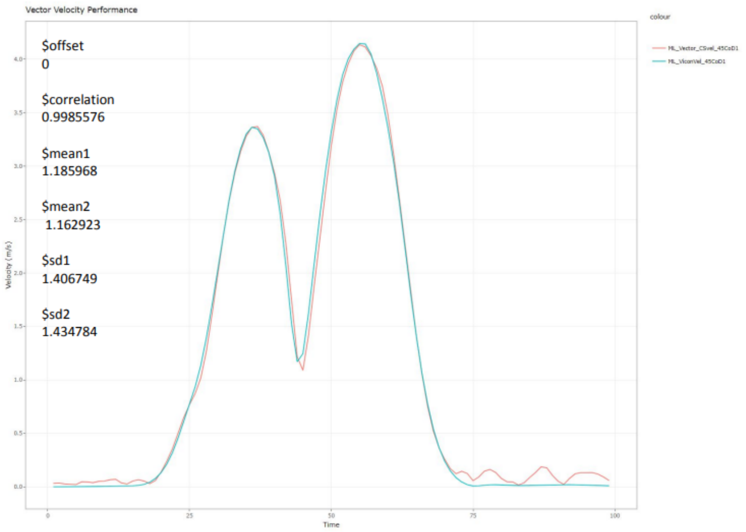
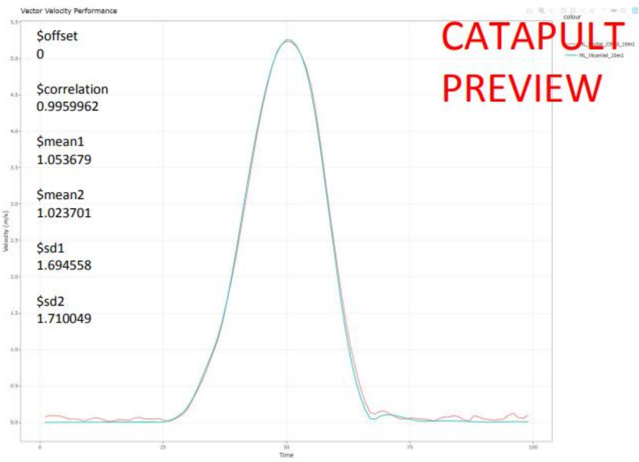


Fig 2. Vector LPS (red) vs Vicon (blue) *Velocity* – 45 degree change of direction task

VECTOR CONCURRENT VALIDITY



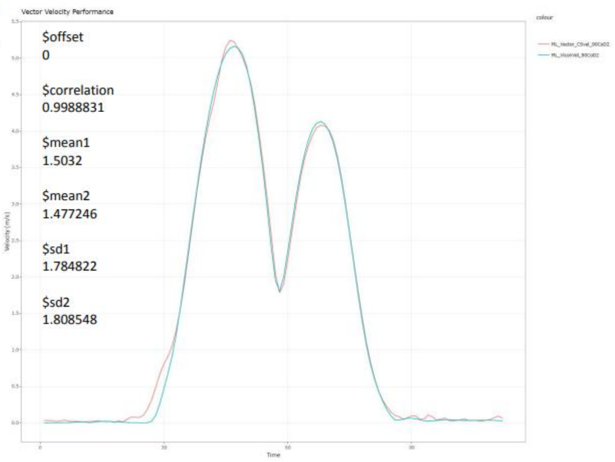


Fig 3 . Vector **LPS** (red) vs Vicon (blue) ***Velocity*** – 10m Linear Sprint task.

Fig 4 . Vector **LPS** (red) vs Vicon (blue) ***Velocity*** – 90 degree CoD task.

VECTOR CONCURRENT VALIDITY

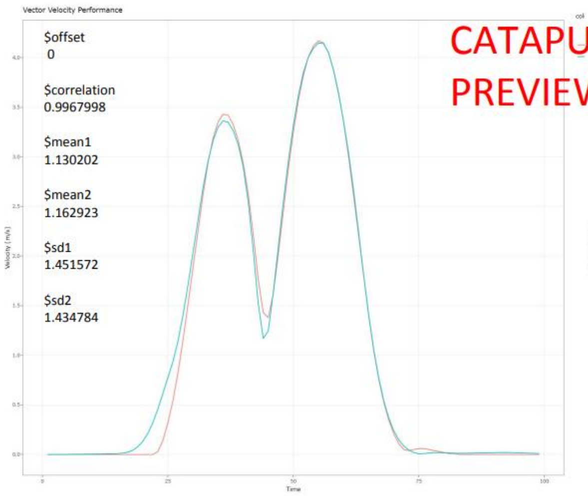


Fig 5. Vector **GPS** (red) vs Vicon (blue) ***Velocity*** – 45 degree change of direction task

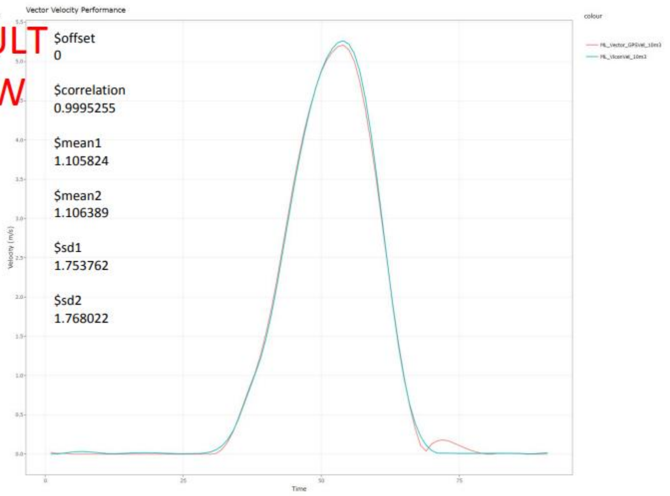


Fig 6 . Vector **GPS** (red) vs Vicon (blue) ***Velocity*** – 10m Linear Sprint task.

VECTOR CONCURRENT VALIDITY

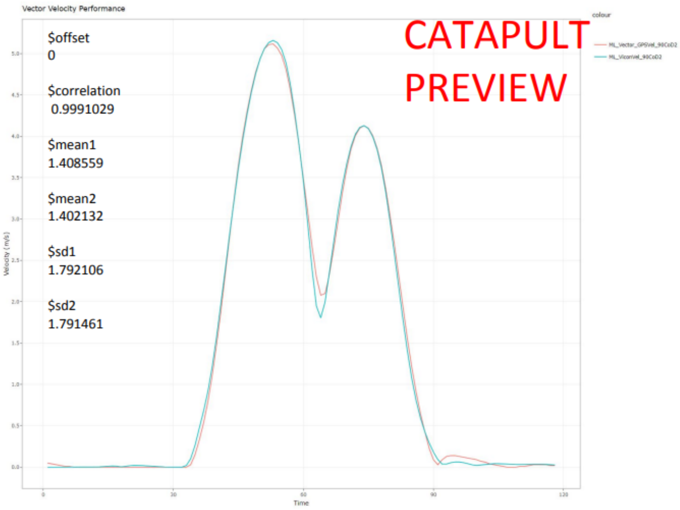


Fig 7 . Vector **GPS** (red) vs Vicon (blue) ***Velocity*** – 90 degree CoD task.

SUMMARY

Early stage analysis indicates a very close relationship between Vector and Vicon, for both linear and multi directional trials.

Larger scale regression analysis is currently in progress for the entire dataset, consisting of 72 total trials over 6 tasks and 4 participants .

[1] Serpiello et al. (2017). Validity of an ultra-wideband local positioning system to measure locomotion in indoor sports. *JSS*

Appendix 2: Vector S7 Device Specifications

DEVICE SPECS

VECTOR DEVICE

DIMENSIONS	81mm x 43mm x 16mm
VOLUME	$48cm^3$
WEIGHT	53g
BATTERY	6 hours
GLOBAL POSITIONING	10Hz GPS, GLONASS & SBAS (or 18Hz GPS)
LOCAL POSITIONING	10Hz Catapult ClearSky
WIRELESS COMMUNICATION	Ultra-wideband & Bluetooth 5
WIRELESS RANGE	Up to 300m (UWB)
CAPACITY	100 athletes
HEART RATE	ECG Derived (Vector S7, G7) & Polar 5.5kHz Compatible (all models)
ACCELEROMETER	3D +/- 16G. Sampled at 1kHz, Provided at 100Hz
GYROSCOPE	3D 2000 degrees/second @ 100Hz
MAGNETOMETER	3D ±4900 μT @100Hz

VECTOR DOCK

NUMBER OF DEVICES	24
BATTERY LIFE	90 minutes

VECTOR RECEIVER

WIFI	2.4 + 5 GHz
WIRELESS DATA	Ultra-wide Band
BATTERY LIFE	9 hours

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