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Between-game variation of physical soccer performance measures in highly trained youth soccer players.

--Manuscript Draft--

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Abstract:	<p>To assess the between-game variation in measures of physical performance during 11 v 11 soccer match-play, over a short period of time, in highly trained youth soccer players. A single cohort observational study design was employed. Physical match performance data were collected from 17 male, highly trained youth soccer players (age: 13.3 ± 0.4 y) over three, 2 x 20min, 11 v 11 matches. Using 10 Hz GPS, the variables selected for analyses were total distance (TD), high-speed running (HSR), very high-speed running (VHSR), number of high-speed running efforts (HSReff) and number of very high-speed running efforts (VHSReff). Match data was also separated into cumulative 5 min epochs, to identify the peak 5 min epoch and the mean of the cumulative 5 min epochs for each match. Variability was quantified using the coefficient of variation (CV), Standard error of measurement (SEM) and intra-class correlation coefficient (ICC). Between- and within-player smallest worthwhile changes (SWC) were also calculated for each variable to aid in the interpretation of the data. Analysis of the variance between games reported a low CV for TD (3.8%) but larger CVs for HSR (33.3%), HSReff (35.4%) and VHSR and VHSReff (59.6 and 57.4 %, respectively). Analysis of 5 min epochs (peak and average) found an increase in the CVs beyond that of the values reported for the whole match. Between-player SWC in high intensity physical performance data ranged from 24.7 - 42.4 %, whereas within-player SWC ranged from 1.2 - 79.9%. The between-game variability of high and very high intensity activities in youth soccer players, across three soccer matches over a short period of time (2 weeks), is relatively 'large' and specific to the individual, thus highlighting the need for caution when interpreting physical performance data between games and players.</p>
Response to Reviewers:	Response to Reviewer's & Editor's comments RE: JSCR-08-8894, entitled "Game to game variation of measures of physical soccer performance in a group of highly trained youth soccer players" Revision Number: 1 Firstly, thank you taking the time to review this manuscript. The comments made by

each Reviewer and the Editor are very much appreciated and we hope that the changes to the manuscript and additional documents, as well as the responses to each of these comments address any concerns.

In addition, the double-spaced line numbers have been provided as these are the ones in which we refer to in the following responses.

Reviewer #1:

General Comments:

This manuscript is certainly adds to the field of applied sports science and provides a thorough analysis of the data. I have suggested changes throughout that should add to the quality of this article.

Title:

The title needs to lose unnecessary words. How about something like "Between-game variation of physical soccer performance measures in highly trained youth soccer players."

Thank you for this suggestion, the title has been amended. Also efforts to continue this phrasing (between-game variation) throughout the manuscript have been made.

Abstract:

The mean and SD age of the players should be stated.

This information has now been added to the abstract – Line 26.

Line 27 and 28: Currently, it is extremely difficult to interpret what any of these variables quantify. The use of "number" is not descriptive enough and should be replace with something like "number of efforts."

Line 28: The phrase, "mean average 5 min epoch," is difficult to understand. However, in the methods section, it is described as the mean of the cumulative 5 min epochs, which is easier to understand; this language should replace the abstract language.

In response to both of the comments above the wording and structure of this section of the abstract has been amended, in an attempt to address these comments – Lines 27 – 31.

Why are the CV values the only data reported? I realize that it is difficult to address all of the data in the short Abstract, but only reporting one of 4 dependent variables seems to highly undervalue the rest of your work, especially since the introduction leads readers to believe that SWC is the research variable of greatest interest. I suggest that at least the SWC data is also reported.

Thank you for this comment, it was difficult to provide a concise abstract in line with the data that is reported within this paper, as suggested though information regarding the SWC values has been added to the abstract – Lines 38 - 39.

Introduction:

This is a very long introduction that seems to focus on the general use of GPS in different scenarios. However, this study is focusing on variability measures that are not well understood by many who may ready this article. Therefore, I think it is worthwhile to discuss what these variables are and how they have been used in applied sports science (what they mean) and remove much of the general talk of GPS use in different populations.

Thank you for this comment and it is now recognised that this section of the manuscript needs to introduce the concept of this paper to a greater degree, rather than assume that the reader is informed and aware of such issues. Consequently, we have attempted to alter the focus of this introduction.

Methods

Somewhere in this section, the training season (in-season, 1 month postseason, etc.) of the players should be stated.

Information to highlight the phase of the season has been added – Line 114-115.

Line 111: Were only three total games played? If so, state the exact number of days separating each game.

Further information to clarify these issues has now been added – Line 112-115.

Line 124: I am assuming that a total of 20 players were tracked throughout this study, but some of the data was unusable. This should be reported. Furthermore, as player position probably affects the data, player position descriptives should be listed. This is much more important, since it seems that 3 subjects were not included in the analyses. The same 20 players (+ 2 goalkeepers) were used to complete the 3 matches within this study, however, 3 of the players chose not to provide written assent or parental consent to be involved in the study, as such no information was obtained in respect to these players and the 11 v 11 matches were simply part of their weekly training schedule. Information to clarify this has been added to the manuscript – Lines 128-132.

Information regarding the player position descriptives has also been provided too – Lines 126-128 but we would also like to note that within these age groups (U12-U14) players are rarely categorised by a single position and therefore positions can be regarded as 'fluid'.

Line 158: Why was a 5 min epoch used? Certainly there is a continuum from one .1 second to an entire game, but 5 min seems to be somewhat arbitrary. If there is good rational or a citation for this duration, it should be addressed.

This was a method we adopted based upon previous research (Bradley et al., 2011; Bradley & Noakes, 2013) in an attempt to identify the 'peak' 5 min period during match-play. However, rather than employ discrete 5 min periods, the current paper looked to utilise a more sophisticated method, for the identification of the 'peak' 5 min period, in which successive (rolling) 5 min periods were used. As, the use of discrete 5 min epochs assumes that the peak 5 min period lies within one of this pre-set periods but this may not be the case. It is recognised this has implications for the cumulative 5 min epochs though, and these are discussed below.

Information to highlight this has been added to the methods section of the manuscript – Line 170-173.

Line 159: I am not sold on the value of the mean of the cumulative 5 min epoch data. There are a few issues. If I understand the methods correctly, the first four and last four minutes of the data should be disproportionally represented. For example, as the epoch moves from 1-5 to 5-9, minute 1 will be measured once, minute 2 will be measured twice... minutes 5 through 36 will be measured 5 times and minute 37 will be measured 4 times, minute 38 will be measured 3 times, and so on. Although I may be interpreting these methods incorrectly, if I am correctly interpreting the methods, the mean of these data will be inappropriately weighted. If I am incorrectly interpreting these methods, the methodology of calculating this metric needs clarification.

Thank you for this comment, we recognise the limitations of this method, however, we unfortunately do not have access to the raw data files anymore, as these raw data are held by the football club and the primary author no longer works for the club. Therefore, we cannot compare the averages of the rolling 5 min epochs (0-5 min, 1-6 min, etc.) to the discrete 5 min epochs (0-5 min, 5-10 min, etc.). The advantages of the current method, however, provide a more sophisticated approach to the identification of the peak 5 min epoch, despite the limitations associated with the cumulative 5 min epochs. In this regard though, the values reported for the reliability statistics for the between game variance in both the peak 5 min epochs and the cumulative 5 min epochs are comparable. Finally, we acknowledge and accept the limitation of this method within the current paper and have addressed this within the discussion (Line 378-382) but this is a small element of the paper with the majority of the paper focusing on the 'whole match' data.

Player load is listed in table 2, but the metric is not defined in the methods section. This variable needs to be defined.

As the main focus of this paper is on locomotor activities, we have decided to remove information regarding the 'Player Load' metric so that the focus of the paper is clear throughout.

Line 168: Describe the methods of acquiring the maximal velocity data. Were the athletes instructed to perform 20 m sprints on some occasion outside of the games? If not, I am assuming maximal linear velocity was not measured and that the % thresholds are actually based off of peak 20 m sprint data acquired during one or all games. This needs further clarification.

The maximal linear velocity was obtained on a separate occasion, prior to the 11 v 11

matches. Information to clarify this has been added – Line 176-180.

Line 176: The ICC methods need to be reported (see Weir, 2005).

Thank you for the relevant reference, as requested the relevant ICC formula has been provided – Line 207-208.

Line 176: Just to clarify, for each dependent variable, for each game comparison (1 vs 2 and 2 vs 3), a plot was made to investigate "heteroscedascity (spelled wrong in the manuscript)?" So, for each dependent variable, two separate plots were made - one for each between game comparison - and all subjects were included in each plot? I am assuming that the CV data were not transformed?

This is correct, but as there was little difference between the correlation values for the raw data and the log transformed data (or those which could be log-transformed) it was decided to not transform the data and perform the analysis on the raw data. As such, if you think this is confusing and not appropriate for this journals readership then we are happy to remove this to avoid any confusion.

Line 178: This makes it seem like some data was transformed and other data was not. This is a serious methodological consideration that needs to be addressed in more detail. Readers need to know exactly what data were transformed as this will also affect future researchers' ability to replicate the analyses performed in this study. The data was assessed for heteroscedascity but not transformed as levels of heteroscedascity were only slightly reduced when the data was log-transformed. A statement regarding this was made on lines 195-201. To try and avoid any confusion information regarding the transformation of any of the data within the statistical analysis section has been removed.

Line 179: The current wording is not descriptive enough to understand the calculation. Replace "difference between repeat measurements" with "between sequential-trials differences." Also, why was the difference between trials 1 and 3 not included?

Changes have been made to the statistical analysis section in an attempt to provide a more thorough overview of the procedures employed within this study. Difference between trials 1 and 3 were not included as this would have equated to 96 hours between trials and therefore to maintain continuity between comparisons (minimum of 48 h rest) only 1v2 and 2v3 were compared.

Results:

Line 210 and 211: Indicate what CVs these are (within or group).

It has now been specified that these were group CVs – line 228.

Lines 212-214: I think this statement belongs in the Discussion.

This statement has now been removed from the results section.

A figure depicting the individual responses for all subjects of at least one dependent variable should be included.

Thank you for this recommendation, it is agreed that this aids in the dissemination of the results. A figure displaying the values for game 1, 2 and 3 for total distance and high speed running (m), for each individual and for the group mean has now been included and integrated into the results section – Figure 1

I also suggest including a figure that depicts the individual responses and the SWC cutoffs for two subjects, one who had low within variance and one who had high within variance. This can be useful as a reference in the discussion.

Thank you for this suggestion again, the addition of such a figure has helped in disseminating the practical application of this study – Figure 2

Discussion

Line 227: It should be mentioned that the sampling rate of the units in the current study were 10 times greater.

Information acknowledging the faster sampling rate in the present study has been added – Line 256-257.

Practical Applications

Line 398: Be sure to indicate that the subjects were youth soccer players.

The focus on 'youth' soccer has been clarified here.

The "Practical Implications" section should be the "Practical Applications" section and should also be the last section in the manuscript and be as short as the current "Conclusions" section. The current Conclusions section should be merged with the Discussion section and not have a heading.

Apologies, the structure of these sections has been addressed as well as the content and length of the practical applications section.

Reviewer #2:

This research aims to provide a quantification of physical performance variability during "sterile" football matches in youth academy players. There appears to be a need to understand game to game variation in performance within some key metrics which are recorded by GPS technology. The study focuses on a specific 2 week window across 3 matches.

The controlled or "sterile" matches should confirm (Methods) that they were competitive (or not), were they part of training season, and if so, what coaching instructions were given. I appreciate the full detail may not be possible but for replication the setting up of the matches and surrounding coaching is important to know.

Information highlighting that these matches were conducted in training has been added – Line 116.

Also, no coaching encouragement was provided (Line 148-149), while we understand this is not realistic to competition it was deemed that we would be unable to standardize the level of coach involvement across the three games, so elected to restrict coach encouragement completely.

Further specific information on current agreed technical variation of GPS metrics should be clarified. Page 4 2nd paragraph reviews this area though does not identify any specific data from other research on variation/precision of GPS devices (satellite related and accelerometry related). This information could then be linked to the variation of movement identified later in the paper.

We acknowledge the need to appreciate the technical variation of GPS metrics, however, due to comments from the other reviewer and associate editor, highlighting the need to maintain an applied focus in the introduction we have respectfully chosen to address this aspect within the discussion section of the paper, we hope that this is acceptable. – Line 258-263.

SWC is noted in methods though not reviewed within the introduction - this should be addressed as the discussion covers this aspect at length.

The concept of SWC has now been introduced within the introduction – Line 82-87.

P7, parag 2 needs reviewing - IS there any rationale for the epoch length chosen? This was a method we adopted based upon previous research (Bradley et al., 2011; Bradley & Noakes, 2013) in an attempt to identify the 'peak' 5 min period during match-play. However, rather than employ discrete 5 min periods, the current paper looked to utilise a more sophisticated method, for the identification of the 'peak' 5 min period, in which successive (rolling) 5 min periods were used. As, the use of discrete 5 min epochs assumes that the peak 5 min period lies within one of this pre-set periods but this may not be the case.

Information to highlight this has been added to the methods section of the manuscript – Line 170-173.

The info about max linear velocity (line 167) should be placed ahead of the comments linked to the different % of HSR etc.

Apologies, this has been moved – Line 176-180.

P8, statistical choices do not appear to be well rationalised. The style of this section may need to be reviewed or confirmation of "best practice" may be drawn if similar data is mentioned in the Introduction (i.e. SWC).

Information rationalising each of the reliability statistics used within the study have

been provided – Line 191-195.

With regards to the SWC, particularly for measures within team sports, there is a contention, as to what is regarded as 'best practice'. This is an area in which we have looked to acknowledge within the discussion – Line 353-370.

P8, Line 195 - is the information on heteroscedascity part of the methods of data processing?

We were unsure about the best section to put this information in, so thank you for this comment as it helped us decide and as a result it has been moved to the statistical analysis (data processing) section – Line 197-201.

Discussion is well written, if overly long, but I feel it is important to include some debate about technical variation of device and how this links to the gross variance identified in physical soccer performance. This may link in to the SWC noted in the paper. At the very least there should be some mention of this. There should be further links to applied practice through the main discussion which then support the Practical Applications section.

Thank you for your comment, we are aware that the discussion section is extensive, however, we feel this is due to the attempts to explain/discuss the data but to then also go beyond this and try and apply this information to practice.

Senior Associate Editor:

In addition to comments from the reviewers above, please address the following.

1. The paper is needs to be more closely aligned with the readership of JSCR. As currently written, the paper appears to be a more generic sport science paper and has much less direct utility to strength and conditioning per se. Please strengthen these connections.

Having reviewed this manuscript in line with the comments provided we recognise that greater efforts to align the current study to the JSCR readership were required, as such there has been a conscious effort to highlight the impact of this research (and related research discussed within this paper) to the readership of JSCR.

2. While acolytes of the Hopkins spreadsheets use the term "typical error", in the rest of the measurement world the proper term is "standard error of measurement", and the adoption of different terminology than that used by the larger biomedical and social sciences literature is unhelpful. Therefore, change TE to SEM.

Apologies, the term 'typical error' has been changed to 'standard error of measurement' throughout the paper.

3. Why initially calculate pairwise SEM values and then an overall SEM? Especially since the pairwise SEM values are not reported in the Results or in Table Two. I strongly encourage you to dump the pairwise SEMs and just report the overall SEMs calculated using the sqrt of the MSE from the repeated measures ANOVA.

Apologise, the pairwise SEM aspect of this section has been removed.

	<p>4. Be specific regarding the ICC model reported, and report the model using the Shrout and Fless / McGraw and Wong system (eg ICC 3,1). Information outlining the ICC model has been added to the statistical analysis section in the manuscript and the relevant reference (Weir, 2005) has been added to the reference list.</p>
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Title: Game to game variation of measures of physical soccer performance in a group of highly trained youth soccer players.

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Title: Between-game variation of physical soccer
performance measures in highly trained youth soccer
players.

22 **Abstract**

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3 23 To assess the between-game variation in measures of physical performance during 11 v 11
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5 24 soccer match-play, over a short period of time, in highly trained youth soccer players. A single
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7 25 cohort observational study design was employed. Physical match performance data were
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10 26 collected from 17 male, highly trained youth soccer players (age: 13.3 ± 0.4 y) over three, 2 x
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12 27 20min, 11 v 11 matches. Using 10 Hz GPS, the variables selected for analyses were total
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14 28 distance (TD), high-speed running (HSR), very high-speed running (VHSR), number of high-
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16 29 speed running efforts (HSReff) and number of very high-speed running efforts (VHSReff).
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19 30 Match data was also separated into cumulative 5 min epochs, to identify the peak 5 min epoch
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22 31 and the mean of the cumulative 5 min epochs for each match. Variability was quantified using
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24 32 the coefficient of variation (CV), Standard error of measurement (SEM) and intra-class
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26 33 correlation coefficient (ICC). Between- and within-player smallest worthwhile changes (SWC)
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29 34 were also calculated for each variable to aid in the interpretation of the data. Analysis of the
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31 35 variance between games reported a low CV for TD (3.8%) but larger CVs for HSR (33.3%),
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34 36 HSReff (35.4%) and VHSR and VHSReff (59.6 and 57.4 %, respectively). Analysis of 5 min
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36 37 epochs (peak and average) found an increase in the CVs beyond that of the values reported for
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39 38 the whole match. Between-player SWC in high intensity physical performance data ranged
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42 39 from 24.7 – 42.4 %, whereas within-player SWC ranged from 1.2 – 79.9%. The between-game
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44 40 variability of high and very high intensity activities in youth soccer players, across three soccer
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46 41 matches over a short period of time (2 weeks), is relatively ‘large’ and specific to the individual,
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49 42 thus highlighting the need for caution when interpreting physical performance data between
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51 43 games and players.

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56 45 **Keywords:** Match-play; reliability; variation; GPS analysis; youth soccer
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INTRODUCTION

Since the introduction and implementation of Global Positioning Systems (GPS) into portable athlete tracking micro-technology, there has been an increase in the volume of scientific literature examining ‘performance’ and training load in team sports (1, 15, 27). The development of such technology has enabled both researchers and practitioners to assess match activity profiles at all levels, including youth soccer (12, 13). **Yet, despite the increase in the use of this technology, there appears to be a lack of research and focus on the between-game variance within the GPS derived variables.** In particular, many studies often neglect to mention or acknowledge the impact of natural variation between games (or session-to-session) within their discussions (19). Failure to acknowledge the variation within such methodologies could greatly affect the interpretation, and therefore the practical implications, of the data and results. **For example, without an appreciation for the short-term, between-game variance, practitioners will be unable to identify whether or not a periodized mesocycle is having a positive effect on physical performance or if players’ physical performance during match-play is subject to accumulated fatigue (i.e. overtraining).**

Team sports performance is stochastic and unpredictable in nature (2), **meaning that the between-game variation is inherent.** In competition, the resultant impact of the opposing team (17), phase of the season (19, 27), weather conditions, substitutions, context of the match (win/lose margin) and current form (6) are all likely to have an influence on players’ physical performance. **Similarly, the number of games analysed will also impact upon the between-game variability, with longer periods of data collection (e.g. a season) demonstrating reduced levels of between-game variability (19, 28).** Consequently, an increased appreciation for the **between-game** variability which is evident during soccer match-play, may begin to allow practitioners and coaches to understand the level of variance that is evident during youth soccer

72 match-play. Thus, allowing them to identify when ‘worthwhile’ or ‘detectable’ changes are
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73 apparent within players’ levels of physical performance.

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75 The variability of physical performance measures have previously been reported for
76 adult populations across a range of football codes including, soccer (19), rugby league (28) and
77 Australian Rules Football (26). From this research it is evident that high intensity activities
78 display high levels of between game variance, with Gregson et al. (19) reporting a coefficient
79 of variations (CVs) of $16.2\% \pm 6.4\%$ for distances covered at an intensity between 19.8 and
80 25.2 km/h, and Kempton et al. (26) reporting high within-player variability for high (>14.4
81 km/h; CV = 11.7-13.8%) and very high-speed running (>19.9 km/h; CV = 15.1-20.9%)
82 between multiple matches. Within the study of Kempton et al. (26) practical application of the
83 data was supported by calculating the smallest worthwhile change (SWC) for each of the
84 measured variables. This provides a measure for which practitioners can use to assess the
85 magnitude of the between-game difference in a measure of physical performance, and therefore
86 if it is ‘worthwhile’ and if so, to what extent (23). This will enable practitioners to assess if
87 there is a difference beyond that of the measured variance, be it positive or negative.

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89 Despite this, there have yet to be any attempts to assess the between-game variability
90 in measures of physical performance in highly trained youth soccer players. Previous studies
91 have tended to focus on the observed variability during small sided games in youth soccer (20,
92 21), rather than during 11 v 11 (as in competition) soccer match-play. This is surprising, when
93 considering the plethora of research which has attempted to evaluate physical performance
94 during competitive youth soccer match-play (10, 11, 12), along with the added issues of growth
95 and maturation in youth populations. Indeed, growth and development is likely to influence
96 players’ physical output capabilities and the inherent heterogeneity in growth and maturation,

1 97 within any cohort of similar aged youth soccer players, is also likely to lead to inter-individual
2 98 variance in both players' physical and metabolic capacities. Without an understanding of the
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4 99 apparent variation within measures of physical performance during match-play, those
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7 100 practitioners working with youth soccer players will be unable to identify the extent to which
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9 101 physical performance has truly been affected by fatigue, growth and maturation and talent
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12 102 development regimes.
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17 104 Consequently, the quantification of the variance within physical performance measures
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19 105 during match-play over a short period of time (2 weeks), in highly trained youth soccer players,
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22 106 may aid in the analysis, interpretation and practical inference of such data by establishing
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24 107 reference values for the SWC in the outcome measures. Therefore, the aim of the present study
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27 108 was to assess the between-game variation in measures of physical performance during 11 v 11
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29 109 soccer match-play over a short period of time (2 weeks), in highly trained youth soccer players.
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33 34 111 **METHODS**

35 36 112 *Experimental Approach to the Problem*

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39 113 Data collection was conducted on three separate 11 v 11 matches, with each match
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41 114 being completed on a separate day following a minimum of 5 days between each match. As
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44 115 such, data collection was undertaken over a 2 week period during the end of a 6 week pre-
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46 116 season training phase. Following initial screening processes, players were involved in three, 11
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49 117 v 11 matches (excluding goalkeepers), which were conducted during training. Matches were
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51 118 comprised of 2 x 20 min halves, with a 5 min rest interval in between halves. Players' match
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54 119 activities were monitored and analysed using 10 Hz global positioning systems (GPS; Catapult,
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56 120 Melbourne, Australia). All testing procedures were preceded by a 10 min warm-up, consisting
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58 121 of low intensity running, dynamic stretching and then moderate intensity running. Following
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122 all matches a 5 min cool down, consisting of low intensity running and static stretching, was
123 conducted.

125 *Subjects*

126 To assess the between-game variation of multiple GPS derived measures obtained
127 during 3 soccer matches, 17 highly trained youth soccer players volunteered to participate (5
128 defenders, 6 midfielders and 6 attackers, with both teams adopting a 4-3-3 formation in each
129 match). As there were only 17 outfield players recruited for the present study, 3 additional
130 outfield players and 2 goalkeepers were used to make up the numbers. As these players did not
131 provide assent (or parental consent), at no point, was any data obtained or analysed in respect
132 to these players and the 11 v 11 matches were simply part of their weekly training within the
133 Academy. All participants were outfield players, aged between 12 and 14 years and from the
134 same Category One Premier League Football Academy. Table 1 displays all anthropometric
135 and screening measures of the players. Maturity status was quantified using self-assessment,
136 Tanner Stage method (35) and maturity offset (29). Ethical approval was granted from an
137 Institutional Ethics Board and all participants, and their parents, were informed of the benefits
138 and risks of the investigation prior to signing an institutionally approved informed consent
139 document to participate in the study. As all participants were under the age of 18, both players
140 and their parents were informed about all procedures and requirements of being involved in the
141 study, before providing written informed assent and consent from participants and parents,
142 respectively.

143 *****Insert Table 1 About Here*****

144 *Procedures*

145 Each match was conducted on the same third generation artificial pitch with the same
146 dimensions (90 x 50 m) and at the same time of day in clear and dry conditions with minimal

177 wind (Averages for temperature, humidity and pressure corresponded to 19.8 ± 2.4 °C, $59.0 \pm$
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3 148 3.4 % and 1009 ± 1 mmHg, respectively over the three matches). Matches were comprised of
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5 149 2 x 20 min halves with a 5 min rest interval between halves with no coaching or external
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7 150 encouragement provided during each match. The composition of the teams and positions
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10 151 remained the same for all three matches, with each participant assigned their own GPS for all
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12 152 matches. Matches were performed on three separate occasions with a minimum of 48 hrs
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15 153 between matches.

19 155 The GPS unit was fitted in a purpose made, size appropriate vest between the scapulae
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22 156 of each player. Units were turned on 10 min prior to the warm-up so that an appropriate signal
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24 157 was obtained prior to data collection. The mean number of satellites during data collection were
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26 158 8.0 ± 0.5 , 8.3 ± 0.4 and 8.2 ± 0.6 for matches 1, 2 and 3 respectively. Furthermore, the mean
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29 159 horizontal dilution of position (HDOP), which is a reflection of the accuracy and quality of the
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31 160 signal were 1.45 ± 0.25 , 1.31 ± 0.11 and 1.31 ± 0.08 for matches 1, 2 and 3 respectively. HDOP
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34 161 values can range between 1 and 50 and an ideal HDOP value of 1 indicates that 1 satellite is
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36 162 above with the remainder equally spaced around the horizon (25). Finally, at all times an ‘open’
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39 163 sky was present and there were no obstructions, ensuring clarity for satellite acquisition.

44 165 Following each match, the GPS data was downloaded and analysed using Catapult
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46 166 Software (Catapult Sprint v5.1.0, Melbourne, Australia) and specially designed Microsoft
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49 167 Excel spreadsheets. Data was recorded for the whole match, each 20 min half and into
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51 168 successive 5 min epochs (e.g. 0 – 5 min, 1 – 6 min, 2 – 7 min, 3 – 8 min, etc.), to establish and
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54 169 quantify the peak 5 min epoch and the mean of the cumulative 5 min epochs throughout each
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56 170 match. This process is similar to that which has been adopted in previous research (7, 8), when
57
58 171 identifying the most intense 5 min period of match-play. In previous research, however,
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172 discrete 5 min periods have been employed (0-5 min, 5-10 min, etc.) as opposed to successive
173 5 min epochs. Information recorded included total distance (TD), metres per min (m/min),
174 relative high speed running distance (HSR), relative high speed efforts (HSReff), relative very
175 high speed running distance (VHSR), relative very high speed efforts (VHSReff) and relative
176 sprint distance (S). To obtain 'relative' measures players' maximal linear velocity was assessed
177 and obtained on a separate occasion prior to the first match. Maximal linear velocity was
178 defined as the maximal velocity obtained during a 20 m straight line sprint from a standing
179 start and obtained from the individual GPS devices, which were then used to record the
180 individual player's physical performance during soccer match-play. Relative HSR running was
181 regarded as distance covered above 50% of maximal linear velocity, relative VHSR was
182 regarded as any distance covered above 70% of maximal linear velocity and relative Sprint as
183 anything above 90% maximal linear velocity. The same thresholds were used for HSReff and
184 VHSReff and an effort was regarded as any occurrence when such a speed was attained and
185 sustained for greater than 0.2 s.

187 *Statistical Analysis*

188 To assess the between-game variation in GPS derived variables across the three soccer
189 matches, results from the three trials were recorded and analysed, generating a coefficient of
190 variation (CV) and a Standard error of measurement (SEM) and a relative measure of reliability
191 an intraclass correlation of coefficient (ICC). These measures of reliability were employed as;
192 1) CVs provide a dimensionless percentage, allowing the reliability of different performance
193 measures to be compared, 2) SEMs provide an indication of the dispersion of the measurement
194 error within a given performance measure, and 3) ICCs provide a measure of relative reliability
195 to assess the stability (rank order) of a group, across repeat trials (3, 32). Firstly, an assessment
196 of the data for heteroscedascity was performed, by formally plotting the absolute difference

197 against the means and calculating the correlation coefficient between units (3). Levels of
198 heteroscedascity were shown to be minimal and were only slightly reduced when the data was
199 log-transformed, however, due to the inability to log transform a '0' value and the occurrence
200 of '0' values for some players within the domain of VHSR, the data was not log transformed
201 and the analysis was performed on the original raw data.

202
203 In the absence of a learning effect an overall SEM was calculated by square rooting the
204 mean square error of a one-way within subjects ANOVA. A group CV (between-player) was
205 calculated by using the 'crude' equation of (SEM/Overall Mean) x 100 (5). Individual (within-
206 player) CVs were calculated by dividing the standard deviation of an individual's repeated
207 performances by the corresponding mean value (22). Finally, an ICC was calculated using the
208 Shrout and Fleiss, ICC 3, 1 formula (36). Furthermore, to aid interpretation, a smallest
209 worthwhile change (SWC) was calculated for within- and between-player variations. The SWC
210 was calculated as a magnitude of 0.5 of the within-player variations (0.5 x individual CVs) and
211 as 0.5 of between-player variations (0.5 x between-player SD) (23, 26, 28). Analysis of the data
212 was aided using the Hopkins (2011) Excel Spreadsheet and the guidance provided by
213 Batterham and George (5). All statistical analyses were performed using SPSS version 21.0
214 (IBM SPSS statistics for Windows, IBM, Armonk, New York) and Microsoft Excel (Microsoft
215 Excel 2013, Microsoft, Redmond, Washington).

216 217 **RESULTS**

218 All players were able to compete for the full duration of the 3 separate matches
219 employed within the study. Examination of the means and standard deviations across the three
220 trials, using repeated measures ANOVAs, did not reveal any evidence of a learning effect or
221 signs of systematic bias ($P > 0.05$), as can be seen in the variance within the trends across the 3

222 matches between TD, HSR and VHSR (Table 1). As a result measures of reliability were
223 obtained by assessing the variance across the three trials. Table 1A, 1B and 1C display the
224 between-game variation in GPS derived variables over the 3 soccer matches for the whole
225 match, the peak 5 min epoch and the mean of the cumulative 5 min epochs throughout each
226 match, respectively.

*****Insert Table 2 About Here*****

228 According to the **group** CVs, Total Distance (TD) covered demonstrated the least
229 amount of variance between games but as the intensity of the movement increases so does the
230 variance within the measurement, with measurements of HSR and HSR efforts presenting CVs
231 ranging from 33.3 – 42.8 % and measurements of VHSR and VHSR efforts presenting CVs
232 ranging from 57.4 – 79.7 %. **This is highlighted in Figure 1, where individual players' physical**
233 **performance in measures of TD display less fluctuation compared to measures of HSR, across**
234 **the three games.**

*****Insert Fig 1 About Here*****

236 **Finally, a wide range of values were presented for the within-player SWC (Table 2).**
237 **Figure 2 presents a comparison of within-player variation between two players, in measures of**
238 **HSR. Despite a similar average value for measures of HSR across the 3 games, player 10 is**
239 **shown to display higher levels of within-player variation compared to player 9, thus**
240 **highlighting the greater levels of between-game variation in player 10 within this measure**
241 **(HSR) of physical performance.**

*****Insert Fig 2 About Here*****

Discussion

244 Present results reveal, when expressed relatively either as a CV or as a SWC, that TD
245 was the most stable GPS derived measure during soccer match-play in highly trained youth

246 soccer players, whether it be the whole match, a peak 5 min period or the mean average of
247 cumulative 5 min epochs. Results also demonstrate, the more intense the action (in both
248 distance covered and efforts performed) the greater the between-game variation, with measures
249 of VHSR (distance and efforts) showing the greatest amounts of variance between games.

250
251 The levels of variance presented for TD within the present study, for the whole match
252 and mean of the cumulative 5 min epochs, are in agreement with those of Coutts and Duffield
253 (14) and McLaren et al. (28). Coutts and Duffield (14) employed a standardized, simulated
254 team sport running circuit to assess the reliability (technical error) in a range of 1 Hz GPS
255 devices and reported intra-unit CVs that ranged from 4.0 – 7.2 %. However, the applicability
256 of these findings to the current results are questionable due to the standardized nature of the
257 task employed within the Coutts & Duffield (14) study and the faster sampling rate of the GPS
258 used (10 Hz) in the present study. Conversely, the study by McLaren et al. (28) assessed the
259 variance in measures of physical performance during competitive adult team sports match-play.
260 McLaren et al. (28) reported a within player CV of 10.0 ± 2.1 % and a between player CV of
261 5.5 ± 1.5 % for TD covered during rugby union competitive match-play, over 15 matches.

262
263 The relative stability shown within the measures of TD covered during soccer match-
264 play provides support for the use of TD as a measure for monitoring physical performance in
265 youth team sports players (24). Although, while the quantification of TD covered can be a
266 useful measure for monitoring training load, and therefore risk of overtraining within soccer
267 players (24). Measures of TD are not recognised as an appropriate measure for evaluating a
268 player's or team's physical performance during match-play (7, 30). This is due to its inability
269 to distinguish between playing level and therefore levels of physical performance (30). Rather,
270 measures relating to high intensity activity (e.g. HSR and VHSR) have been shown to

1 271 distinguish between playing level, with elite level players performing more high intensity
2 272 activities when compared to their untrained counterparts (30). Consequently, measures of high
3
4 273 intensity activity, not TD covered, are commonly used as an indicator of physical performance
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7 274 within soccer match-play.
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11
12 276 With respect to between-game variance, the current values presented for measures of
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14 277 high and very high intensity activities (HSR, VHSR, HSReff and VHSReff), however, are
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17 278 larger than those previously reported within the literature (14, 28, 33). Rampinini et al. (33)
18
19 279 reported CVs of 4.7% and 10.5% for HSR and VHSR activities, respectively, when using 10
20
21
22 280 Hz GPS devices, whereas Coutts and Duffield (14) reported CVs of 11.2 - 32.4% and 11.5 –
23
24 281 30.4% for high and very high intensity running, respectively, across a range of different GPS
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27 282 devices. However, the methods adopted within both these studies required the participants to
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29 283 complete a standardized course rather than assess them during competitive soccer match-play.
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33
34 285 Competitive soccer match-play is random and unpredictable, meaning that the variance
35
36 286 in the activities and intensities between games is more diverse than that which is experienced
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39 287 during standardized drills. Furthermore the likely higher levels of intrinsic variability
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41 288 (Physical, tactical and technical immaturity) within youth soccer players also contributes to the
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44 289 existing levels of high variance, which have already been demonstrated within competitive
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46 290 adult team sports (19, 28). The potential presence for further variance within youth players'
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48
49 291 physical, technical and tactical maturity is likely to exacerbate the heterogeneity within
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51 292 locomotor characteristics, and therefore between-game variance, within youth soccer match-
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54 293 play. Consequently, the culmination of high levels of intrinsic variability and extrinsic
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56 294 variability are likely to result in even larger levels of between-game variance, as demonstrated
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58 295 within the present study.
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296 Using a large sample size of professional adult soccer players ($n = 485$), Gregson et al.
297 (19) assessed the variation in physical performance during competitive matches over a long (a
298 season) and short (8 week) term period. These authors reported a CV of $17.7 \pm 6.8\%$ and 23.5
299 $\pm 21.8 \%$ for total high speed running (>19.8 km/h), over a long and short term, respectively.
300 The larger standard deviation evident in the short term, total high speed running, within the
301 study of Gregson et al. (19) supports the large variation evident within the present study, which
302 is prevalent in soccer match-play over a short period of time. Consequently, the evidence
303 suggests that the variation between games, in measures of physical performance, increases as
304 the period of data collection decreases, a theory which would be substantiated by the current
305 results which were collected over a period of 2 weeks. Although in elite rugby union players,
306 McLaren et al. (28) conducted a similar study which assessed the variability in measures of
307 physical performance across 15 competitive matches. McLaren et al. (28) reported within-
308 player CVs of 27.6 ± 6.9 and $68 \pm 19\%$, and between-player CVs of 16.5 ± 5.1 and 58 ± 63 for
309 measures of HSR and VHSR, respectively. While current results present a larger level of
310 variance than those reported by McLaren et al. (28), it appears that the assessment of physical
311 performance during competitive team sports results in a substantial increase in the between-
312 game variance in both high and very high intensity activities, with larger variances apparent
313 across shorter time periods and in higher intensity domains. Furthermore, the positional
314 variance, in terms of physical performance, within soccer is arguably more diverse than rugby
315 union.

316
317 The ICCs show reduced values for the peak 5 min epochs and cumulative 5 min epochs,
318 when compared to the ICCs for data from the whole matches. While the ICC is employed as a
319 common statistical method for assessing the reliability of a measure, it is dependent on the
320 stability to which a particular measure holds its position within the sample, across repeat tests

321 and is therefore dependent upon the sample heterogeneity, unlike CV (5). This means that the
322 greater the spread of the scores or range within the measured variable, the greater the magnitude
323 of the ICC (5). Consequently, the reduced ICCs within the peak 5 min epochs and cumulative
324 5 min epochs are likely to be a result of the greater homogeneity within the sample, and as such
325 may not be an appropriate measure of reliability to use when analysing physical performance
326 within a group of highly trained soccer players. Although, CVs for measures of physical
327 performance within the peak and mean of cumulative 5 min epochs do provide further evidence
328 to suggest that the levels of variance are greater when analysing the data in these predefined
329 epochs. Consequently, researchers and practitioners should be aware of the potentially
330 increased variance when analysing performance data in smaller epochs, particularly as this will
331 have an impact upon the interpretations of the results.

332
333 Current findings demonstrate large differences in the smallest worthwhile changes
334 (SWC) in physical performance data, from one game to another. Data also supports previous
335 findings that show that as the intensity increases so does the range in the within SWC (%)
336 variation (19, 26, 28), a finding which is likely associated with, but not limited to, the reduced
337 reliability of measurement devices at higher velocities, **demonstrated during standardized**
338 **running drills** (14, 15). When examining the within-athlete SWC, it is clear to see that there is
339 a large variation among players with regards to what would be considered as a ‘worthwhile’
340 effect between matches. For example, the within-player SWC ranged from 1.2 – 46.9 % for
341 HSR (during a whole match), this suggests that there are substantial inter-individual differences
342 in between-game variations, with regards to what would be noted as a ‘worthwhile’ change
343 **(Fig 2)**. Such differences maybe a consequence of position (e.g. defenders vs. midfielders vs.
344 attackers), as some positions may result in a greater amount of between-game variance (e.g.
345 wingers involvement in a game may vary more compared to a centre midfielder) (26).

346 Consequently, there is a need to be aware of what is regarded as a ‘worthwhile’ change for
347 each individual, particularly as the present results seem to suggest that a group SWC could
348 result in incorrect interpretations of players’ performance, which could then have a subsequent
349 impact upon training practices and periodization.

350
351 It is important to note however, it is not the absolute level of variance which is of sole
352 importance, rather, it is the magnitude of the ‘noise’ compared to both the usually observed
353 changes (signal) and the changes that may have a practical effect (9). Moreover, the calculation
354 of the appropriate magnitude for the SWC within measures of physical performance in team
355 sports (which are not categorical measures of success) is less straightforward. This is due to
356 the fact that there is no current evidence to demonstrate that changes greater than any fraction
357 of the between-athlete standard deviation or the individual CV are meaningful in practice (9).
358 Nevertheless, the utilisation of such a measure provides researchers and practitioners with data
359 that can be employed to make a more informed decision about the physical performance of the
360 players, either as a group (team) or on an individual basis (23). To date, similar research has
361 adopted the magnitude of 0.2 when calculating the SWC in measures for team sports
362 performance (26, 28), however, due to the observed variance which is clearly evident in
363 competitive soccer match-play, a larger magnitude of 0.5 may provide those analysing the data
364 with more confidence when deciding whether or not a change is ‘worthwhile’. Consequently,
365 there is a necessity for those involved in team sports to understand the level of variance and
366 sensitivity that is apparent within physical performance data during competition and within the
367 time period that is being assessed (context-specific). This will allow sports practitioners and
368 researchers to evaluate if any observed differences, from one game to another are meaningful.

370 The current sample size is substantially lower than those within the literature which
371 have examined the variability of physical performance data over a longer period of time (19,
372 28). The aim of the current study, however, was to assess the variability in physical
373 performance data over a short-period of time (2 weeks), providing thresholds and context
374 specific data, which can be utilised to see if there has been an effect on players' physical
375 performance during competition over a similar period of time (i.e. from week-to-week) or
376 between players. Furthermore, limitations regarding the cumulative 5 min match splits (0-5, 1-
377 6, 2-7 min, etc.) and the calculation of the mean of the cumulative 5 min epochs should be
378 recognised. The current method of 'splitting' the data is viewed as a more sophisticated method
379 than the use of discrete 5 min epochs (0-5, 5-10 min, etc.), employed in previous research (7,
380 8), for the identification of the 'peak' 5 min epoch. The current results, however, provide a
381 starting point and a framework for the understanding, analysis and interpretation of the
382 variability in physical performance data during soccer match-play. Finally, the current match
383 conditions aimed to negate the influence of extraneous variables, such as opposing team,
384 playing conditions and external encouragement. The impact, however, of environmental
385 conditions, live score difference (win/loss margin), player proximity to the ball, as well as the
386 magnitude and frequency of other technical and tactical actions all have the potential to
387 influence the variability of physical performance data. These measures, however, were beyond
388 the scope of the present study. The quantification and exploration of the contribution of these
389 extraneous variables to the between-game variability would further enhance our understanding
390 of match-play variability.

391
392 With the development in micro-technology (GPS) and its common use for assessing
393 physical performance in competition, there is a need to understand the level of variance in the
394 information provided, in a context-specific manner (e.g. youth soccer match-play). Current

395 results demonstrate that the between-game variation across three youth soccer matches, over a
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2
3 396 short period of time, is substantially larger than values previously reported in the literature.
4
5 397 Within-player variations, however, appear to demonstrate large differences between players, a
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7 398 finding which may be a consequence of player characteristics, positional demands, tactical
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10 399 roles and fitness levels. The present findings highlight the difficulties associated with both the
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12 400 interpretation of GPS derived variables (i.e. physical performance) and also the use and
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14 401 application of measures of high and very high intensity activities as indicators of performance.
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16
17 402 Finally, practitioners should be aware of the potentially large levels of between-game variance
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19 403 within youth soccer match-play, as this is likely to have implications for training practices,
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22 404 interpretation of measures of physical performance, training periodization and potentially
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24 405 talent identification.

406

407 **PRACTICAL APPLICATIONS**

408 The current study provides a process which may be particularly useful for those
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34 409 involved in the prescription of training programmes, talent identification and monitoring of
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36 410 both training load and performance. For example, in the current data set (for a whole match) a
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39 411 between-athlete SWC of 17.6% was calculated for HSR, this demonstrates the large changes
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41 412 in measures of physical performance which are necessary to be regarded as a meaningful
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44 413 difference among a group of highly trained youth soccer players, when assessing performances
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46 414 within a short period of time (across 2 weeks), which has implications for the interpretation of
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49 415 performance measures which are increasingly obtained within elite level youth soccer. In
50
51 416 contrast, however, the within SWC (%) present a potentially different approach to analysing
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54 417 physical performance within youth soccer players, on an individual level. Present data suggests
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56 418 that the 'within-athlete' SWC may be substantially lower than the 'between-athlete' SWC for
57
58 419 some individuals. As a result the assessment and calculation of within-athlete SWC (individual
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420 variations) for each player will allow sports practitioners and researchers to assess the between-
421 game variability on an individual level. **This approach may have particular relevance within**
422 **the domain of talent development. Indeed,** a practical goal may be to maintain a player's level
423 of physical performance but reduce the amount of variance within their physical performance,
424 thus making their levels of physical performance more consistent. **Moreover, practitioners may**
425 **wish to monitor the extent to which a particular training mesocycle has impacted upon a**
426 **player's physical performance or examine the extent to which growth and maturation is**
427 **impacting upon a player's physical performance during match-play.** Consequently, applied
428 sports practitioners and researchers should examine the extent of the between-game variation
429 and SWC in their own cohort of players and in each of the relevant performance measures.
430 This should be done both as a team and individually and, if data permits, on a positional level.

431

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434 participation in the project.

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3 569 Fig 1: Individual players' values and the group mean for total distance (TD) and high speed
4 running (HSR) for each of the three matches.
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9 572 Fig 2: A comparison between two players (midfielders) for high speed running across the three
10 matches and between the respective player's coefficient of variation (CV) and smallest
11 worthwhile change (SWC).
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Table 1: Anthropometric and screening measures of the players ($n=17$).

Variable	Mean \pm Standard Deviation	95% Confidence Intervals
Age (y)	13.3 \pm 0.4	13.1 - 13.5
Stature (m)	1.59 \pm 0.11	1.54 - 1.64
Body Mass (Kg)	48.9 \pm 10.1	43.9 - 53.9
Maturity Offset (y)	-0.8 \pm 0.9	-1.2 to 0.3
Σ 4 Skinfolds (mm)	30.7 \pm 5.1	28.3 - 33.1
Tanner Stage	3 \pm 1	2 - 3
Training Years (y)	4.4 \pm 2.1	3.4 - 5.3
Training Hours (hrs.p.week)	12.4 \pm 2.3	11.3 - 13.5

Note: Skinfolds used for the Σ 4 skinfolds were the biceps, triceps, subscapular and superilliac (Durnin & Womersley, 1974).

Table 2: Game-to-game variation from GPS derived variables (95% Confidence Intervals) during 3 sterile soccer matches for A) the whole match B) the peak 5 min epoch and C) the mean of the cumulative 5 min epochs throughout each match.

A	Match			Mean	SD	ICC	SEM (m)	CV (%)	SWC	
	1	2	3						Between (%)	Within (%)
TD (m)	4553	4412	4634	4533	418	0.85 (0.71 - 0.93)	171 (142 - 230)	3.8 (3.0 - 5.4)	2	0.3 – 4.5
HSR (m)	1174	942	728	948	472	0.52 (0.24 - 0.74)	316 (262 - 424)	33.3 (26.1 – 46.0)	17.6	1.2 – 46.9
VHSR (m)	81	193	107	127	107	0.43 (0.61 - 0.39)	75 (62 - 101)	59.6 (46.7 - 82.3)	30.7	5.6 – 78.0
HSR efforts (n)	87.4	59.4	53.4	66.7	31.1	0.36 (0.06 - 0.64)	24 (20 - 32)	35.4 (27.7 - 48.8)	14.7	3.4 – 44.2
VHSR efforts (n)	5.5	12.8	7.6	8.6	6.9	0.40 (0.10 - 0.66)	5 (4 - 7)	57.4 (45.0 - 79.2)	29.0	3.9 – 79.9
B	Match			Mean	SD	ICC	SEM (m)	CV (%)	SWC	
	1	2	3						Between (%)	Within (%)
TD (m)	624	632	647	634	80	0.23 (-0.06 - 0.54)	71 (59 - 96)	11.2 (8.8 - 15.5)	4.2	0.7 – 14.6
HSR (m)	136	190	154	160	70	0.40 (0.11 - 0.67)	53 (44 - 71)	33.2 (26.0 - 45.8)	15.3	1.9 – 37.4
VHSR (m)	25	47	29	33	29	0.30 (0.00 - 0.59)	24 (20 - 32)	72.1 (56.6 - 99.5)	26.7	9.3 – 86.6
HSR efforts (n)	22	31	24	26	10	0.36 (0.06 - 0.63)	8 (7 - 11)	31.4 (24.6 - 43.3)	14.4	1.1 – 31.7
VHSR efforts (n)	4	8	5	6	5	0.32 (0.02 - 0.61)	5 (3 – 6)	71.4 (56.0 - 98.5)	26.7	6.2 – 88.6
C	Match			Mean	SD	ICC	SEM (m)	CV (%)	SWC	
	1	2	3						Between (%)	Within (%)
TD (m)	559	537	569	555	49	0.81 (0.65 - 0.91)	22 (18 - 30)	4.0 (3.1 – 5.5)	2.2	0.4 – 4.7
HSR (m)	69	102	77	83	40	0.33 (0.03 - 0.61)	31 (26 - 42)	37.5 (29.4 - 51.8)	16.3	3.8 – 52.1
VHSR (m)	8	21	12	14	13	0.15 (-0.13 - 0.47)	11 (9 - 15)	78.1 (61.2 - 107.8)	34.3	7.1 – 86.6
HSR efforts (n)	13	19	12	15	7	0.21 (-0.06 - 0.52)	6 (5 - 8)	42.8 (33.6 - 59.1)	18.6	3.3 – 53.1
VHSR efforts (n)	2	4	2	3	2	0.14 (-0.15 - 0.45)	2 (1 - 3)	79.7 (62.5 - 110.0)	36.0	8.5 – 86.6

Note: SD =Standard Deviation; ICC =Intraclass Correlation Coefficient; SEM =Standard Error of Measurement; CV =Coefficient of Variation; SWC =Smallest Worthwhile Change.

Figure 1



