Reliability of internal and external load parameters in recreational football for health

Abstract

There is limited research focussed around the analysis of internal and external load parameters during football health programs. The aim of this study was to assess the reliability of internal and external load parameters in this activity. 30 subjects were enrolled (mean ± SDs; age = 43 ± 3 years, weight = 84 ± 14 kg, height = 176 ± 7 cm, BMI = 27.1 ± 3, VO_2max = 40.7 ± 3.4 $ml \cdot kg \cdot min^{-1}$). The football matches (five a-side) took place on an artificial grass outdoor field (pitch size of 36 x 18.5 meters). Participants completed the match (60 minutes) and replicated the same match a week later. The analysis took into account several parameters: Heart rate (HR), total distance (TD), high speed running (HSR), number of accelerations (>2 $m \cdot s^{-2}$), and metabolic power (MT). We found good scores of reliability in several parameters: TD (ICC = 0.66), accelerations (ICC = 0.62), mean HR (ICC = 0.82), HSR (ICC = 0.77), and MP (ICC = 0.66). The results reported in this study revealed good scores of absolute reliability (ICC), and small/trivial effect size.

Keywords: GPS technology; team sports; soccer; futsal

Introduction

Several studies have reported the validity of recreational team sports (e.g. football) as a means to improve the health of general population (Andersen, Schmidt, Pedersen, Krustrup, & Bangsbo, 2016; Bangsbo, Junge, Dvorak, & Krustrup, 2014; Krustrup et al., 2009; Pedersen et al., 2017). Football is played worldwide at the professional level, making it the world's most popular sport (Reilly & Williams, 2003), therefore its popularity could be used to improve the sports adherence to health programmes. Football is an effective physical activity able to induce physiological benefits such as, significantly improving blood pressure, lowering heart rate at rest, blood parameters (e.g. systolic and diastolic blood pressure), as well as improving maximal aerobic power (VO_{2max}) (Krustrup et al., 2010; Krustrup et al., 2013).

Football is a team sport characterised by an intermittent model where aerobic and anaerobic components are taxed (Impellizzeri et al., 2008). The measurement of internal and external load parameters in conjunction could guarantee a more accurate knowledge of football activity and its physical demands, which could offer several advantages about its use as a health activity (Stevens, De Ruiter, Beek, & Savelsbergh, 2016). Information about the reliability of football as a health activity is therefore paramount, especially considering football is an acyclic and unpredictable activity and every match has different load demands (Los Arcos, Martínez-Santos, Yanci, Martín, & Castagna, 2014; Thomas. Reilly, 2005). Despite the popularity and wide appeal of this sport, no one has systematically investigated the reliability of internal and external load parameters in middle-aged males. The only evidence that exists about the reliability of internal load parameters, in such activity, shows a reliability of mean HR (typical error of measurement) of 2.4% (CI 90% 1.6; 3.1) (Beato, et al., 2016).

Global Positioning Systems (GPS) is the technology widely utilised to quantify the external load parameters in team sports (Vickery et al., 2014). GPS systems are used to collect and analyse time-motion data such as, total distance covered (TD), number of changes of direction, acceleration and deceleration activities, as well as time spent at high speed running (HSR) (Cummins, Orr, & Connor, 2013; Varley, Fairweather, & Aughey, 2012; Vickery et al., 2014). GPS accuracy, validity and reliability have been widely investigated (Coutts & Duffield, 2010; Johnston, Watsford, Kelly, Matthew, & Spurrs, 2014; Scott et al., 2016) with generally positive results, although they have revealed some limitations in accuracy. Nevertheless, there is enough evidence to justify the use of such technology (10 Hz GPS) in order to evaluate external load parameters during recreational football activity (Beato, Bartolini, et al., 2016; Coutts & Duffield, 2010; Scott et al., 2016).

Presently, there is little research focussed on the analysis of internal and external load parameters during football health programs, and these studies are limited by a lack of information regarding the reliability of the parameters analysed. The main purpose of this study was to assess the reproducibility of internal and external load parameters in recreational football (day-to-day reliability) using GPS.

Methods

Subjects: 30 male subjects without specific pathologies were enrolled in this study during 2014 (mean ± SDs; age = 43 ± 3 years, body mass = 84 ± 14 kg, height = 176 ± 7 cm, body mass index (BMI) = 27.1 ± 3.1, fat mass 19.5 ± 4.1%; HRmax = 177.2 ± 7.3, VO_2max = 40.7 ± 3.4 $ml \cdot kg \cdot min^{-1}$). All procedures were approved by the Ethics Committee of the Department of Neurological and Movement Sciences, University of Verona (Italy) and conducted according to the declaration of Helsinki for human studies of the World Medical Association.

Experimental protocol and data analysis: A maximal running incremental test was used to determine VO_2max and HRmax. An automated metabolic cart was used to measure respiratory parameters breath-by-breath (Quark b2, Cosmed, Italy). This study utilised the protocol recently published by the same research group (Beato, et al., 2016).

The football matches designed as small sided games (SSGs) five a-side took place on an artificial grass outdoor field (pitch size of 36 x 18.5 meters). Participants completed recreational football matches (60 minutes) and replicated the same match a week later (every participant played 2 times). Each player on each team took turns playing as the goalkeeper (changing goalkeepers every 5 minutes). Training load parameters were recorded by means of 10 Hz GPS system (STATSports, Viper system, Northern Ireland, UK). Validity of this GPS system has been verified in previously conducted research (Beato, et al., 2016b). GPS data was analysed by the STATSport Viper Software Version 1.2. The analysis considered several internal and external load parameters: %HRmax, TD measured in metres, HSR over 14.4 km h^{-1}, number of accelerations and decelerations performed (>2 $m \cdot s^{-2}$), relative velocity calculated as the ratio between TD and the total time (Christopher, Beato, & Hulton, 2016; Gaudino et al., 2013). In addition, GPS recorded data about metabolic power (MP) measured in $w \cdot kg^{-1}$ and high intensity metabolic power distance over 20 w kg^{-1} (HMD) (Osgnach, Poser, Bernardini, Rinaldo, & Di Prampero, 2010). The indirect estimation of the MP utilised the rationale that accelerated running on a flat terrain is energetically analogous to uphill running at constant speed (Minetti et al., 2002). Ecological validity of MP in football has been previously reported by, Manzi, Impellizzeri, & Castagna (2014).

Statistical analysis

Data are presented as means ± 1 SD. A Shapiro-Wilk test was performed for the evaluation of the normality (assumption) for statistical distribution. Log transformation was done for non-normal data. Pearson's Correlation Coefficient reported in this study as well as the variance explained (R^2) was used to determine the relationship between the match data (for both matches) (Hopkins, 2000). Statistical significance was set at $p < 0.05$. Absolute reliability of HR data (between Match 1 and Match 2) was assessed using the typical error of measurement (TEM) and interclass correlation (ICC). ICC interpretation is expressed as: poor < 0.4, fair > 0.4, good > 0.6, excellent > 0.75 (Cicchetti, 1994). Differences between Match 1 and Match 2 were reported as a mean of change with confidence intervals (CI 90%) (Hopkins, 2000). Paired t-test was performed between Match 1 and Match 2 for each variable to identify systematic change. The Cohen's d (ES) was calculated to determine the magnitude of effect (comparison between Match 1 and Match 2) by standardizing the coefficients according to the appropriate between-subjects standard deviation. Furthermore, the Cohen's d (ES) was assessed using the following criteria: trivial < 0.2, small > 0.2, medium > 0.5, large > 0.8 (Cohen, Rozeboom, Dawes, & Wainer, 1990). Statistical analysis was performed using SPSS (SPSS Statistics 20.0) for Mac OS X Yosemite.

Results

Data recorded during Match 1 and Match 2 were (means ± 1 SD): mean HR = 146.1 ± 9.7 bpm and 144.6 ± 9.3 bpm respectively, $p = 0.61$, ES = 0.15 (trivial), %HRmax 82.4% ± 4.5 and 81.6% ± 5.1 respectively, $p = 0.55$, ES = 0.17 (trivial), TD 3483 ± 215 m and 3375 ± 330 m respectively, $p = 0.29$, ES = 0.39 (small), accelerations number 38 ± 5 and 37 ± 5 respectively, $p = 0.33$, ES = 0.2 (small), decelerations number 36 ± 5 and 35 ± 5 respectively, $p = 0.37$, ES = 0.2 (small), MP 6.53 ± 0.4 $w \cdot kg^{-1}$ and 6.48 ± 0.41 $w \cdot kg^{-1}$ respectively, $p = 0.75$, ES = 0.13 (trivial), relative velocity 63.8 ± 7.2 $m \cdot min^{-1}$ and 61.8 ± 7.8 $m \cdot min^{-1}$ respectively, $p = 0.22$, ES = 0.27 (small), HSR 71.2 ± 9.2 m and 68.1 ± 10.5 m respectively, $p = 0.19$, ES = 0.32 (small), HMD 246.5 ± 50.7 m and 241.6 ± 48.1 m respectively, $p = 0.66$, ES = 0.10 (trivial). Reliability of the internal and external load parameters are presented in table 1.

Discussion

The results reported in this study revealed good/excellent scores of absolute reliability (ICC and TEM), as well as a small mean of change, and small/trivial ES (between Match 1 and Match 2) in every parameter. This new evidence strongly supports the utilisation of football as a health activity and underlines the stability of internal and external load parameters between matches.

This study reports a mean HR equivalent to 82% HRmax during matches, a value higher than that recommended by ACSM (Thompson & ACSM, 2009). This result underlines that football can be utilised as a means of aerobic training, capable of improving physiological parameters (Garber, Blissmer, Deschenes, Franklin, & Lamonte, 2011). Further, the mean HR reported in this study is like previous research examining the internal/external workloads of recreational football (Bangsbo et al., 2014). After the replication of matches, HR presented an excellent reliability score: mean HR (ICC = 0.82) and % HRmax (ICC = 0.78). Our results support previous results reported in studies on recreational football (reliability HR, CV = 2.4%) (Beato et al., 2016) and results obtained when analysing professional football players during 6 a-sided games (reliability HR, ICC = 0.85, and %HR max, ICC = 0.61) (Stevens et al., 2016).

GPS is a technology commonly used in professional football in order to evaluate external load parameters (Coutts & Duffield, 2010). In this study we reported good/excellent scores of reliability in several parameters: TD (ICC = 0.66), accelerations (ICC = 0.62), decelerations (ICC = 0.65), MP (ICC = 0.66), relative velocity (ICC = 0.81), HSR (ICC = 0.77), and HMD (ICC = 0.81) (Cicchetti, 1994). Our results reveal a high level of reliability for all the external load parameters (table 1). This data cannot be compared to other data previously published on this topic (football for health), but they can be compared with reliability data of small sided games (SSG) in football (4 x 7 min 6 vs. 6, pitch size of 40 x 34 m) (Stevens et al., 2016). Stevens et al, (2016) also revealed high scores of reliability for several external load parameters: TD (ICC = 0.84), accelerations (ICC = 0.74), MP (ICC = 0.78), HSR (0.74), and high metabolic power > 20 w·kg (ICC = 0.75). The results reported in this study closely mirror the results reported by Stevens et al, (2016), showing almost the same scores. This study supports previous research in professional football players demonstrating repeated SSGs yield reliable external workload parameters, providing further support for the use of SSGs as an appropriate training stimulus for health interventions

This study also considered traditional external load parameters (e.g. TD, relative velocity), as well as, metabolic and power parameters (e.g. MP, HMD, accelerations). Power activities such as changes of direction, short shuttle runs and accelerations strongly affect the activity energy cost (Zamparo, Bolomini, Nardello, & Beato, 2015). For instance, the energy cost of short shuttle runs (with a change of direction of 180°), is from 3 to 7 times larger than that of linear running (Zamparo et al., 2015). Furthermore, the estimated MP, such as accelerations counts, could better distinguish the existing differences in locomotor performance than HR in isolation (Osgnach et al., 2010). Therefore, the results obtained in this study may also be utilised to expand upon the current existing knowledge on energy expenditure in recreational football that is currently missing (Beato, et al., 2016b).

This paper reports two main limitations. The reliability of internal and external load parameters was analysed during two football matches (day-to-day reliability). The reliability of workload parameters between two matches would likely be affected by several factors, such as fitness and skill of opposition players, and a larger sample of matches is required to better understand stability of workload parameters during recreational football. However, this study presented a large sample of 30 subjects that is representative of the typical population that partake in recreational football, and certain controls can be made to improve the reliability of workload parameters such as matching opposing players for skill and fitness. The second limitation is associated with the use of GPS (10 Hz). GPS are devices largely used in football and team sports (Cummins et al., 2013). Several researchers have reported validity and reliability of these devices, however such technology is not without limitations (Beato, Bartolini, et al., 2016; Cummins et al., 2013). Previous studies have reported some criticisms about the capacity of GPS such as, its inability to accurately record high speed and high metabolic power actions (Buchheit & Simpson, 2016). Researchers and sport scientists should be conscious of the potential limitations of this technology regarding accuracy.

In conclusion, this study has proven the reliability of internal and external load parameters in such recreational activity. The current research providing further support for the use of SSGs as an appropriate training stimulus for health interventions This new evidence offers several practical applications in the design of recreational football protocols for health.

Acknowledgements

We thank all the subjects enrolled during the study for their support.

References

Andersen, T. R., Schmidt, J. F., Pedersen, M. T., Krustrup, P., & Bangsbo, J. (2016). The effects of 52 weeks of soccer or resistance training on body composition and muscle function in +65-year-old healthy males – A randomized controlled trial. *PLOS ONE*, *11*(2), e0148236.

http://doi.org/10.1371/journal.pone.0148236

Bangsbo, J., Junge, A., Dvorak, J., & Krustrup, P. (2014). Executive summary : Football for health – prevention and treatment of non-communicable diseases across the lifespan through football. *Scandinavian Journal of Medicine & Science in Sports*, *24*(Suppl. 1), 147–150. http://doi.org/10.1111/sms.12271

Beato, M., Bartolini, D., Ghia, G., & Zamparo, P. (2016). Accuracy of a 10 Hz GPS unit in measuring shuttle velocity performed at different speeds and distances (5 – 20 M). *Journal of Human Kinetics*, *54*(1), 15–22. http://doi.org/10.1515/hukin-2016-0031

Beato, M., Impellizzeri, F. M., Coratella, G., & Schena, F. (2016). Quantification of energy expenditure of recreational football. *Journal of Sports Sciences*, *34*(24), 2185–2188. http://doi.org/10.1080/02640414.2016.1167280

Buchheit, M., & Simpson, B. M. (2016). Player Tracking technology: half-full or half-empty glass? *International Journal of Sports Physiology & Performance*, Epub ahead of print.

Christopher, J., Beato, M., & Hulton, A. T. (2016). Manipulation of exercise to rest ratio within set duration on physical and technical outcomes during small-sided games in elite youth soccer players. *Human Movement Science*, *48*, 1–6. http://doi.org/10.1016/j.humov.2016.03.013

Cicchetti, D. V. (1994). Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychological Assessment*, *6*(4), 284–290. http://doi.org/10.1037/1040-3590.6.4.284

Cohen, J., Rozeboom, W., Dawes, R., & Wainer, H. (1990). Things I Have Learned (So Far). *American Psychologisy*, *45*(12), 1304–1312.

Coutts, A. J., & Duffield, R. (2010). Validity and reliability of GPS devices for measuring movement demands of team sports. *Journal of Science and Medicine in Sport*, *13*, 133–135. http://doi.org/10.1016/j.jsams.2008.09.015

Cummins, C., Orr, R., & Connor, H. O. (2013). Global positioning systems (GPS) and microtechnology sensors in team Sports: a systematic review. *Sports Medicine*, *43*, 1025–1042. http://doi.org/10.1007/s40279-013-0069-2

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., & Lamonte, M. J. (2011). Quantity and quality of exercise for developing and maintaining neuromotor fitness in apparently Healthy Adults : Guidance for Prescribing Exercise. *Medicine and Science in Sports and Exercise*, *11*, 1334–1359. http://doi.org/10.1249/MSS.0b013e318213fefb

Gaudino, P., Iaia, F. M., Alberti, G., Strudwick, a. J., Atkinson, G., & Gregson, W. (2013). Monitoring training in elite soccer players: Systematic bias between running speed and metabolic power data. *International Journal of Sports Medicine*, *34*(11), 963–968.

http://doi.org/10.1055/s-0033-1337943

Hopkins, W. (2000). Measures of reliability in sports medicine and science. *Sports Medicine*, *30*, 1–15.

Impellizzeri, F. M., Rampinini, E., Castagna, C., Bishop, D., Bravo, D. F., Tibaudi, A., & Wisloff, U. (2008). Validity of a repeated-sprint test for football. *International Journal Sports Medicine*, *29*, 899–905. http://doi.org/10.1055/s-2008-1038491

Johnston, R. J., Watsford, M. L., Kelly, S. J., Matthew, J. P., & Spurrs, R. W. (2014). Validity and interunit reliability of 10 Hz GPS units for assessing athletes movement demands. *Journal of Strength and Conditioning Research*, *28*(6), 1649–1655.

Krustrup, P., Aagaard, P., Nybo, L., Petersen, J., Mohr, M., & Bangsbo, J. (2010). Recreational football as a health promoting activity: a topical review. *Scandinavian Journal of Medicine & Science in Sports*, *20*(Suppl. 1), 1–13. http://doi.org/10.1111/j.1600-0838.2010.01108.x

Krustrup, P., Nielsen, J. J., Krustrup, B. R., Christensen, J. F., Pedersen, H., Randers, M. B., … Bangsbo, J. (2009). Recreational soccer is an effective health-promoting activity for untrained men. *British Journal of Sports Medicine*, *43*, 825–832. http://doi.org/10.1136/bjsm.2008.053124

Krustrup, P., Randers, M. B., Andersen, L., Jackman, S. R., Bangsbo, J., & Hansen, P. R. (2013). Soccer improves fitness and attenuates cardiovascular risk factors in hypertensive men. *Medicine and Science in Sports and Exercise*, *45*(3), 553–560. http://doi.org/10.1249/MSS.0b013e3182777051

Los Arcos, A., Martínez-Santos, R., Yanci, J., Martín, J., & Castagna, C. (2014). Variability of objective and subjective intensities during ball drills in youth soccer players. *Journal of Strength and Conditioning Research*, *28*(3), 752–757. http://doi.org/10.1519/JSC.0b013e3182a47f0b

Manzi, V., Impellizzeri, F., & Castagna, C. (2014). Aerobic fitness ecological validity in elite soccer players: a metabolic power approach. *Journal of Strength and Conditioning Research*, *28*(4), 914–919. http://doi.org/10.1519/JSC.0000000000000239

Minetti, A. E., Moia, C., Roi, G. S., Susta, D., Ferretti, G., Alberto, E., … Ferretti, G. (2002). Energy cost of walking and running at extreme uphill and downhill slopes. *Journal of Applied Physiology*, *93*, 1039–1046.

Osgnach, C., Poser, S., Bernardini, R., Rinaldo, R., & Di Prampero, P. E. (2010). Energy cost and metabolic power in elite soccer: A new match analysis approach. *Medicine and Science in Sports and Exercise*, *42*(1), 170–178. http://doi.org/10.1249/MSS.0b013e3181ae5cfd

Pedersen, M., Vorup, J., Nistrup, A., Wikman, J., Alstrøm, J., Melcher, P., … Bangsbo, J. (2017).

Effect of team sports and resistance training on physical function, quality of life, and motivation in older adults. *Scandinavian Journal of Medicine & Science in Sports*, *Printing*.

Reilly, T. (2005). An ergonomics model of the soccer training process. *Journal of Sports Sciences*, *23*(6), 561–572. http://doi.org/10.1080/02640410400021245

Reilly, T., & Williams, A. M. (2003). *Introduction to science and soccer*. (T. Reilly & A. Williams, Eds.). London: Routledge.

Scott, T. U., Scott, T. J., & Kelly, V. G. (2016). The validity and reliability of global positioning system in team sport: a brief review. *Journal of Strength and Conditioning Research*, *30*(5), 1470–1490.

Stevens, G. A. T., De Ruiter, C. J., Beek, J. P., & Savelsbergh, P. J. G. (2016). Validity and reliability of 6-a-side small-sided game locomotor performance in assessing physical fitness in football players. *Journal of Sports Sciences*, *34*(6), 527–534. http://doi.org/10.1080/02640414.2015.1116709

Thompson, W., & ACSM. (2009). *ACSM's Guidelines for Exercise Testing and Prescription* (Edition Ei). Lippincott Williams and Wilkins.

Varley, M. C., Fairweather, I. H., & Aughey, R. J. (2012). Validity and reliability of GPS for measuring instantaneous velocity during acceleration , deceleration , and constant motion. *Journal of Sports Sciences*, *30*(2), 121–127. http://doi.org/10.1080/02640414.2011.627941

Vickery, W. M., Dascombe, B. J., Baker, J. D., Higham, D. G., Spratford, W. A., & Duffield, R. (2014). Accuracy and reliability of GPS devices for measurement of sports-specific movement patterns related to cricket, tennis, and field-based team sports. *Journal of Strength and Conditioning Research*, *28*(6), 1697–1705.

Zamparo, P., Bolomini, F., Nardello, F., & Beato, M. (2015). Energetics (and kinematics) of short shuttle runs. *European Journal of Applied Physiology*, *115*(9), 1985–1994. http://doi.org/10.1007/s00421-015-3180-2

Table 1. Reliability internal and external load parameters recorded during Match 1 and Match 2.

Variables	**Mean of change (CI 90%)**	**TEM (CI 90%)**	**ICC (CI 90%)**	**R^2**
Mean HR (bpm)	-1.50 (-3.3; +0.3)	4.06 (3.35; 5.19)	0.82 (0.70; 0.90)	0.67
%HR (HRmax)	-0.80 (-1.8; +0.2)	2.28 (1.88; 2.92)	0.78 (0.63; 0.88)	0.60
TD (m)	-107.6 (-189; -25.7)	186 (154; 238)	0.66 (0.45; 0.80)	0.42
Accelerations (n°)	-0.37 (-1.69; +1.16)	3.47 (2.87; 4.44)	0.62 (0.39; 0.78)	0.36
Decelerations (n°)	- 0.27 (-1.68; +1.15)	3.23 (2.66; 4.13)	0.65 (0.44; 0.80)	0.40
MP (w kg^{-1})	-0.05 (-0.15; +0.06)	0.24 (0.29; 0.31)	0.66 (0.45; 0.80)	0.42
RV ($m \cdot min^{-1}$)	-1.94 (-3.44; -0.44)	3.41 (2.88; 4.37)	0.81 (0.67; 0.89)	0.63
HSR (m)	-3.19 (-5; -1.20)	4.34 (3.58; 5.55)	0.77 (0.66; 0.85)	0.66
HMD (m)	-4.97 (-11.8; +1.86)	15.5 (12.8; 19.9)	0.81 (0.73; 0.85)	0.71

Typical error of measurement (TEM), ICC = Interclass Correlation, CI = Confidence Intervals, R^2 = Variance, TD = Total Distance, MP = Metabolic Power, RV = Relative Velocity, HRmax = Maximum Heart Rate, HSR = High Speed Running over 14.4 km h^{-1}, HMD = High Intensity Metabolic Power Distance over 20 w kg^{-1}.