LJMU Research Online

Kyprianou, E, Lolli, L, Haddad, HA, Di Salvo, V, Varley, MC, Mendez Villanueva, A, Gregson, W and Weston, M

 A novel approach to assessing validity in sports performance research: integrating expert practitioner opinion into the statistical analysis

http://researchonline.ljmu.ac.uk/id/eprint/12878/

Article

1 **Abstract**

2

3 **Purpose**: Maximal sprinting speed is decisive in soccer, placing great importance on the

4 valid measurement of this variable. Through equivalence testing, we used expert practitioner

5 opinion to evaluate 10-Hz Global Positioning System (GPS) validity for measuring maximal

6 sprinting speed. **Methods**: We surveyed practitioners on issues related to the measurement

7 of maximal sprinting speed and also assessed twelve elite youth soccer players performing

8 two maximal 40 m sprints, measured by 10-Hz GPS units and a criterion measure (100-Hz

9 Laser). Setting equivalence bounds as practitioner opinion of the practically acceptable

10 amount of measurement error for maximal sprinting speed, we assessed agreement between

11 GPS and Laser. **Results**: Survey respondents (n=50) reported using a combination of

12 methods for deriving maximal sprinting speed (tests, training, match) but the majority did

13 not assess system validity. The median value of practically acceptable amount of

14 measurement error for maximal sprinting speed was 0.20 m/s. Maximal sprinting speed was

15 8.79 ± 0.33 m/s (Laser) and 8.75 ± 0.32 m/s (GPS) and the mean difference was 0.04 (90%

16 confidence interval -0.03 to 0.11) m/s. Equivalence testing using 0.2 m/s as lower (-0.2 m/s)

17 and upper (+0.2 m/s) thresholds, or as a range (-0.1 to +0.1 m/s), showed Radar Gun and

18 GPS as most likely and likely equivalent measures, respectively. **Conclusions**: Assessed

19 against our expert-informed equivalence thresholds, GPS-measured maximal sprinting

20 speed is equivalent to that recorded by a criterion. When measuring maximal sprinting speed

21 over 40 m, GPS can be used with confidence.

22

23 **Key Words:** Validation; Equivalence Testing; GPS; Soccer; Peak Velocity

Introduction

In soccer, maximal sprinting represents the most infrequent match activity recorded by elite male youth soccer players.[1,2] Despite this, the practical importance of sprinting is shown via straight-line sprints preceding a high percentage of goals scored and match sprint distance being greater for successful compared to unsuccessful teams.[3] As such, players' ability to sprint at high velocities is decisive and therefore practitioners regularly use sprint tests to inform training prescription and manage player physical preparation.[4] Furthermore, the measurement and interpretation of training and match distances in speed zones defined relative to players' maximal sprinting speed, opposed to arbitrary zone classification, could help practitioners prescribe an appropriate training stimulus that minimises negative consequences of an inaccurate prescription and quantification of workload.[5-7]

Fully automatic timing systems, laser guns and high-speed video are considered to be gold standards for measuring sprinting speed,[8] yet Global Positioning Systems (GPS) are more accessible and easier to use in daily practice. As such, GPS are now frequently used in team sports to measure and monitor player running velocities during training and matches.[9] However, it is important that practitioners have confidence in systems used to measure maximal sprinting speed, especially when systems are noncriterion measures.[6] Validity studies are therefore fundamental in the development of alternate measures that save costs, facilitate analyses, and enable data field-based collection.[10]

Validity studies compare a new, or more practically feasible measure against a gold standard (criterion), and if the difference in measures is sufficiently small, validity is assumed. For example, the difference in 40 m maximal sprinting speed measured via 10-Hz GPS and a radar gun was trivial (-0.8%; 90% confidence interval -1.1 to -0.4%) and so GPS was concluded to provide a valid measure of maximal sprinting speed.[6] While this study and others[11] clearly represent a valued additions to the literature, between-system differences were interpreted against standardised thresholds which are influenced by heterogeneity.[12-14] Furthermore, effect (e.g., difference) magnitude should be evaluated according to its practical relevance and a standardised scale may not be relevant to the research question.[14] Indeed, team sport researchers and practitioners should not be constrained by interpreting practical relevance via standardised thresholds. An alternate approach here could be the

54 gathering of information on what constitutes the smallest important difference through

55 gauging expert/end-user opinion[15] as practitioner insight can represent a catalyst for external

56 validity.[16]

57 Recently, equivalence testing has been suggested to have potential for advancing

58 measurement research in exercise science.[10] This approach assesses whether two

59 measurement systems are statistically equivalent by comparing the differences against a pre-

60 determined 'area of equivalence'. The concept of statistical equivalence is, however, heavily

61 influenced by the choice of the equivalence region[10] and here the use of standardised

62 thresholds as benchmarks is considered a last resort.[17] Relying on standardised effect sizes

63 as justification from the smallest effect size of interest should therefore be avoided. What

64 may be of more[13] relevance to practitioners and researchers in sport and exercise science is

65 setting equivalence thresholds around the smallest numerical value, in raw units, that

66 experts perceive practically relevant. As such, the aims of the present study were twofold, 1)

67 to survey expert opinion on issues surrounding the measurement of maximal sprinting speed

68 in elite soccer, and 2) to assess the validity of GPS as a measure of maximal sprinting speed

69 using equivalence testing informed by surveyed expert opinion.

70 **Methods**

71 **Maximal Sprinting Speed Survey**

72 To obtain information on issues related to the maximal sprinting speed measurement, we

73 conducted a short cross-sectional survey. Here, practitioners (sport scientists, strength and

74 conditioning coaches, and fitness coaches) currently working in elite soccer, were asked

75 about perception and practices of their teams maximal sprinting speed measurement. The

76 survey was circulated privately to known contacts with data collected using an online survey

77 platform (Online Surveys, formerly Bristol Online Surveys [BOS]). The survey consisted

78 of ten questions, covering two main areas: 1) introduction/ informed consent and

79 background information (Questions 1 to 5), and 2) issues related to the measurement of

80 maximal sprinting speed (Questions 6 to 10), of which all were multiple choice questions.

Participants and Study Design for the Maximal Sprinting Speed Assessment

Twelve full-time male youth soccer players (age 16.3 ± 0.8 years, body mass 54.5 ± 1.2 kg, height 173.9 ± 6.2cm) were recruited from an elite academy. All players were participating in ~8 training sessions per week, combining soccer, strength and conditioning training, and competitive play. This observational study conformed to the Declaration of Helsinki and received ethics approval from the Aspire Zone Research Committee and the Anti-Doping Laboratory Institutional Review Board, Qatar (approval number E20140000012).

Methodology

Validity of 10-Hz global positioning systems (GPS) units against a criterion measure (100-Hz Laser) was tested for maximal sprinting speed. All testing was undertaken on an outdoor natural grass pitch and all players wore their regular soccer boots. Participants performed two maximal 40-m sprints (Trial 1, Trial 2) with three minutes rest between efforts. Typical errors for the between-trial differences were 0.13 (90% confidence interval 0.10 to 0.20) m/s for Laser and 0.07 (0.06 to 0.11) m/s for GPS, and intraclass correlation coeffcients were 0.85 (0.64 to 0.95) and 0.95 (0.88 to 0.98), respectively. Maximal sprinting speed was assessed simultaneously via 10-Hz GPS (Catapult Optimeye S5, version 7.32) and Laser (Laveg LDM 300C, Jenoptik, Germany). Each sprint was recorded using a hand-held digital video recorder (SONY AX53 4K) to allow precise time alignment between GPS and Laser. Each GPS unit was inserted into the manufacturer provided vest that was fitted tightly to the players, holding the receiver between the scapulae. All devices were activated 15 min before data collection to allow acquisition of satellite signals in accordance with the manufacturer's instructions.[18] The average horizontal dilution was 0.68 ± 0.04 and the average number of satellites per unit was 12.0 ± 0.0. Laser was calibrated with zero showing the start of the 40 m measured sprint and was centred on the middle of the running lane. Laser height was 1.2 m and all measurements were taken from the centre of the lens which was 3.1 m behind the starting line. The laser beam was directed at the lower part of the players back. After recording, GPS data were downloaded to a computer and analyzed using the manufacture's software (Catapult Openfield Software, version 1.21.1).[6] The raw GPS velocity data are calculated using the Doppler-shift method.[19] Laser data were processed using the software associated with the device (das3e). Displacement-time data were captured at 100-Hz and analyzed with a 51-point moving average, and from this an instantaneous velocity trace was derived. The

112   velocity trace was used to establish the maximal velocity that occurred within the 40 m measured

113   sprint.

Statistical Analysis

115   All survey data are presented as response frequency (expressed as a percentage) or where

116   appropriate, the median and interquartile range (IQR). The peak value attained from either

117   Trial 1 or Trial 2 was used as the maximal sprinting speed recorded by the two different

118   measurement systems. Using the *TOSTER* package,[13] we assessed for statistical equivalence

119   between our two measurement systems using two one-sided tests (TOST), as per the

120   guidelines for assessing agreement between a surrogate measure (GPS) with a known

121   criterion measure (Laser).[10] For equivalence testing, users need to define the targeted

122   region,[10] so we set the lower and upper equivalence bounds from the median value that

123   experts surveyed perceived as the acceptable amount of measurement error. Here, the

124   median value of 0.20 m/s was represented by the upper end of the response category given

125   that question on the acceptable amount of measurement error contained categories

126   encompassing a range of measurement error (e.g., 0.15 – 0.20 m/s). As such, our equivalence

127   bounds were specified before results are known.[13] Given that measurement error is random

128   (i.e., + or -), we acknowledge the potential for ambiguity when asking survey respondents

129   on the practically acceptable amount of measurement error. As such, we assessed for

130   equivalence using the median value as the lower and upper equivalence bounds (-0.20 m/s,

131   +0.20 m/s) and also as a range spanning 0.2 m/s, giving lower and upper equivalence bounds

132   of -0.10 m/s and +0.10 m/s, respectively. Results of equivalence tests can be obtained by

133   mere visual inspection of the confidence interval,[13] with statistical equivalence between the

134   two measures concluded when the 90% confidence interval around the mean difference

135   excludes the lower and upper equivalence bounds.[13] However, to avoid test interpretation

136   via the dichotomy of null hypothesis significance testing,[20,21] we assessed equivalence on a

137   continuous scale. This was done via conversion of the t statistics from both one-sided tests

138   to a probability (via the t-distribution), with subsequent equivalence probability interpreted

139   using a one-sided calibrated Bayes.[22-24] Here, probabilities were interpreted using the

140   following scale: 75–95%, likely; 95-99.5%, very likely; >99.5%, most likely,[25] and

141   equivalence was indicated by the lower probability.[10,13] Analyses were performed in R

142 (version 3.4.1, R Foundation for Statistical Computing, Vienna, Austria). Uncertainty in all

143 estimates is presented as 90% confidence intervals.

144

145 **Results**

146 Median time (min:sec) to complete the survey was 02:57 (02:08,4:27) and of 50

147 respondents, 60% were sports scientists, 32% fitness coaches, and 8% strength and

148 conditioning coaches (Question two). Respondents had a median of 8 (5,12) years'

149 experience working in elite soccer (Question three) and worked at predominantly European

150 soccer clubs (76%) (Question five). Where respondents selected a combination of methods

151 for deriving maximal sprinting speed (Question nine), the majority of responses were for

152 the combination of match and training (55%). The median value for the practically

153 acceptable amount of measurement error for maximal sprinting speed (Question ten) was

154 0.20 (0.10,0.25) m/s. For this question, two respondents chose 'Other' and provided exact

155 values of 5% and 0.6 km/h, respectively; the latter of these values was included in the

156 appropriate answer category giving a total of 49 answers for this question (Figure 1).

157 Sprint times were 8.72 ± 0.34 m/s (Trial 1) and 8.71 ± 0.28 m/s (Trial 2) for Laser, and 8.69

158 ± 0.32 m/s (Trial 1) and 8.72 ± 0.29 m/s (Trial 2) for GPS. The mean of the players' fastest

159 sprint from either Trial was 8.79 ± 0.33 m/s (Laser) and 8.75 ± 0.32 m/s (GPS) and the mean

160 difference was 0.04 (90% confidence interval -0.03 to 0.11) m/s. Equivalence of maximal

161 sprinting speeds measured by Laser and GPS was most likely (probability 100%) when using

162 0.2 m/s as the lower and upper thresholds (Figure 2a), and likely (probability 93.7%) when

163 using 0.2 m/s as a range (Figure 2b).

164 **Discussion**

165 Maximal sprinting speed is key in soccer, so measurement validity is needed, especially when

166 systems are not a gold standard measure. Therefore, in this study we employed a novel

167 approach for assessing GPS validity as a measure of maximal sprinting speed by using

168 equivalence testing informed by expert practitioner opinion. We found that GPS-measured

169 maximal sprinting speed was likely to very likely equivalent to a criterion, gold standard measure

170 and therefore practitioners should have confidence in GPS as a measure maximal sprinting speed.

171   Additionally, our survey results provide valuable insights into current practices surrounding the

172   measurement of maximal sprinting speed in elite soccer.

173   While previous work has shown validity of 10-Hz GPS for measuring maximal sprinting

174   speed,[6] criterion comparison was made via standardisation. Standardised scales, however,

175   lack practical context and may therefore not be relevant to the research question.[14] This is

176   by no means a criciticism as establishing externally valid minimum important differences

177   represents a huge challenge to sport and exercise science as changes in one variable need to

178   be assessed against subsequent changes in a relevant anchor such as performance.[15] Use of

179   expert opinion therefore represents a credible approach to informing the definition of

180   practically important differences or, in the context of our study, an acceptable amount of

181   measurement error for measures relevant to sports performance.[26] Generally, reliability

182   studies in this research domain have entailed, to a great extent, the indiscriminate

183   calculation of Pearson's correlation coefficients,[27] or the definition of the typical error of

184   the estimate expressed in percentage points whose magnitude assessment may be irrelevant

185   for both the researcher and practitioner.[28] Notwithstanding the deceptive simplicity and

186   specious practicality of calculating these common statistics, failure to express the actual

187   amount of measurement error adopting a meaningful metric may limit practitioner definition

188   of what represents a true population increase in the response of interest deemed substantially

189   greater than a predefined practically important difference.[26] Further, tests of mean

190   difference are common in agreement research but may not neccessarily represent the best

191   statistical approach.[10] Equivalence testing has been proposed as a more appropriate method

192   for evaluating agreement among measures than mean difference tests; however, choosing

193   and justifying equivalence regions is a difficult aspect of this approach.[10] Indeed, previous

194   studies using equivalence testing have reported, yet not justified the smallest effect size of

195   interest for the equivalence bounds.[13] Therefore, we attempted to overcome these

196   methdological concerns by setting our equivalence bounds on what a relatively large sample

197   of experienced practitioners perceived to be an acceptable amount of measurement error

198   when measuring maximal sprinting speed. This novel and rigourous approach enabled us to

199   conclude that the GPS-measured maximal sprinting speed is likely to most likely equivalent

200   to the speed recorded by a gold standard measure (Laser).

201 For accurate assessment of maximal sprint speed, fully automatic timing systems represent the
202 gold standard with dual-beamed photocells, laser guns and high-speed video timing representing
203 cheaper, more practical tools with acceptable accuracy.[8] The results presented in this study lend
204 the first emprical support of this observation given that 84% of survey respondents perceived
205 either laser/ radar guns, fully automatic timing systems and timing gates as gold standard measures.
206 Only 16% of respondents regarded GPS as gold standard despite these systems being the most
207 frequent system (34%) used to measure maximal sprinting speed in the field. Our findings help to
208 address this apparent disconnect as practitioners can be assured of the validity of maximal sprinting
209 speeds recorded by 10-Hz GPS. The infrequent nature of system validity checks observed in our
210 study possibly reflects a lack of available time given that practitioners are indeed cognisant of the
211 need for validity assessments.[29]

212 The most common single method to derive maximal sprinting speed in our survey was fitness tests.
213 The neeed for sprint testing was recently questioned as peak speeds recorded during matches were
214 faster than when recorded during a 40-m maximal running test, albeit in semi-professional senior
215 players.[9] These findings contrast with previous work whereby highly trained youth footballers'
216 maximal match speeds were ~90% of the speed attained on a 40-m sprint test.[30 31] In light of these
217 equivocal findings, it is encouraging that survey respondents derived maximal sprinting speeds
218 from a variety of scenarios (e.g., tests, training, matches). Such an approach will help to ensure an
219 on-going calibration of maximal speeds, which is of vital importance if these speeds are used to
220 inform the classification of relative speed zones.[6]

Practical Applications and Conclusion

221
222 Despite not being perceived as a gold standard measure of maximal sprinting speed by the
223 experts we surveyed, speeds recorded by 10-Hz GPS were equivalent to a gold standard
224 measure, thereby supporting validity. Utilising an approach that overcomes methodological
225 concerns with traditional validation studies, our data therefore strengthen the confidence[6]
226 practitioners can take from using GPS to assess maximal sprinting speed. Furthermore,
227 using GPS to measure maximal sprinting speed during fitness tests negates the need for
228 more expensive and less accessible testing equipment, resulting in less time burdensome
229 tests. Whether or not practitioners continue to use dedicated sprint tests to assess maximal
230 sprinting speeds may well depend on the purpose of the test. For example, dedicated

231 sprinting tests clearly have worth if used to benchmark physical progression but may well
232 be unnecessary if the sole purpose is to establish maximal speeds to inform relative training
233 and match activity zones. Indeed, our survey shows that fitness tests are no longer the sole
234 method used by practitioners for measuring maximal sprinting speeds. As training and
235 match data are now used by practitioners to assess maximal speeds, future research should
236 build on our findings by examining the whether maximal speeds are more frequently
237 occuring during training or matches. Such research would have important implications for
238 informing player preparation and performance evaluation strategies.

243 **Figure Legends**
244 **Figure 1.** Responses (n=49) for the practically acceptable amount of measurement error for
245 maximal sprinting speed (Question ten)
246 **Figure 2a.** Mean difference (m/s) and uncertainty for the difference (90% confidence
247 interval) in maximal sprinting speed measured by Laser and GPS. The black vertical dashed
248 lines represents the expert-informed statistical equivalence region of 0.2 m/s, expressed as
249 the lower and upper threshold.
250 **Figure 2b.** Mean difference (m/s) and uncertainty for the difference (90% confidence
251 interval) in maximal sprinting speed measured by Laser and GPS. The black vertical dashed
252 lines represents the expert-informed statistical equivalence region of 0.2 m/s, expressed as
253 a range.

254 **Reference List**
255 1. Harley JA, Barnes CA, Portas M, et al. Motion analysis of match-play in elite U12 to U16 age-
256   group soccer players. *J Sports Sci* 2010;28(13):1391-7. doi:
257   10.1080/02640414.2010.510142 [published Online First: 2010/10/23]
258 2. Varley M, Gregson W, McMillan K, et al. Physical and technical performance of elite youth
259   soccer players during international tournaments: influence of playing position and team

260 success and opponent quality. *Sci Med Footb* 2017;1(1):18-29. doi:
261 10.1080/24733938.2018.1427883

262 3. Yang G, Leicht AS, Lago C, et al. Key team physical and technical performance indicators
263 indicative of team quality in the soccer Chinese super league. *Res Sports Med*
264 2018;26(2):158-67. doi: 10.1080/15438627.2018.1431539 [published Online First:
265 2018/02/01]

266 4. Pyne DB, Spencer M, Mujika I. Improving the value of fitness testing for football. *Int J Sports*
267 *Physiol Perform* 2014;9(3):511-4. doi: 10.1123/ijspp.2013-0453 [published Online First:
268 2013/11/16]

269 5. Murray NB, Gabbett TJ, Townshend AD. The use of relative speed zones in australian football:
270 are we really measuring what we think we are? *Int J Sports Physiol Perform*
271 2018;13(4):442-51. doi: 10.1123/ijspp.2017-0148 [published Online First: 2017/09/06]

272 6. Roe G, Darrall-Jones J, Black C, et al. Validity of 10-HZ GPS and timing gates for assessing
273 maximum velocity in professional rugby union players. *Int J Sports Physiol Perform*
274 2017;12(6):836-39. doi: 10.1123/ijspp.2016-0256 [published Online First: 2016/10/14]

275 7. Mendez-Villanueva A, Buchheit M, Simpson B, et al. Match play intensity distribution in youth
276 soccer. *Int J Sports Med* 2013;34(2):101-10. doi: 10.1055/s-0032-1306323 [published
277 Online First: 2012/09/11]

278 8. Haugen T, Buchheit M. Sprint running performance monitoring: methodological and practical
279 considerations. *Sports Med* 2016;46(5):641-56. doi: 10.1007/s40279-015-0446-0
280 [published Online First: 2015/12/15]

281 9. Massard T, Eggers T, Lovell R. Peak speed determination in football: is sprint testing necessary?
282 *Sci Med Footb* 2018;2(2):123-26. doi: 10.1080/24733938.2018.1427883

283 10. Dixon PM, Saint-Maurice PF, Kim Y, et al. A primer on the use of equivalence testing for
284 evaluating measurement agreement. *Med Sci Sports Exerc* 2018;50(4):837-45. doi:
285 10.1249/mss.0000000000001481 [published Online First: 2017/11/15]

286 11. Beato M, Coratella G, Stiff A, et al. The validity and between-unit variability of GNSS Units
287 (STATSports Apex 10 and 18 Hz) for measuring distance and peak speed in team sports.
288 *Front Physiol* 2018;9 doi: 10.3389/fphys.2018.01288

289 12. Hopkins WG. Improving meta-analyses in sport and exercise science. *Sportscience*
290 2018;22:11-17.

291   13. Lakens D, Scheel AM, Isager PM. Equivalence testing for psychological research: a tutorial.
292   *Adv Methods Pract Psychol Sci* 2018;1(2):259 - 69. doi: 10.1177/2515245918770963

293   14. Pek J, Flora DB. Reporting effect sizes in original psychological research: a discussion and
294   tutorial. *Psychol Methods* 2018;23(2):208-25. doi: 10.1037/met0000126 [published Online
295   First: 2017/03/10]

296   15. Thorpe RT, Atkinson G, Drust B, et al. Monitoring fatigue status in elite team-sport athletes:
297   implications for practice. *Int J Sports Physiol Perform* 2017;12(Suppl 2):S227-s34. doi:
298   10.1123/ijspp.2016-0434 [published Online First: 2017/01/18]

299   16. Esculier JF, Barton C, Whiteley R, et al. Involving clinicians in sports medicine and
300   physiotherapy research: 'design thinking' to help bridge gaps between practice and
301   evidence. *Br J Sports Med* 2018 doi: 10.1136/bjsports-2018-100078 [published Online
302   First: 2018/10/29]

303   17. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical
304   primer for t-tests and ANOVAs. *Front Psychol* 2013;4:863. doi:
305   10.3389/fpsyg.2013.00863 [published Online First: 2013/12/11]

306   18. Duffield R, Reid M, Baker J, et al. Accuracy and reliability of GPS devices for measurement
307   of movement patterns in confined spaces for court-based sports. *J Sci Med Sport*
308   2010;13(5):523-5. doi: 10.1016/j.jsams.2009.07.003 [published Online First: 2009/10/27]

309   19. Varley MC, Jaspers A, Helsen WF, et al. Methodological considerations when quantifying
310   high-intensity efforts in team sport using global positioning system technology. *Int J Sports*
311   *Physiol Perform* 2017;12(8):1059-68. doi: 10.1123/ijspp.2016-0534 [published Online
312   First: 2017/01/05]

313   20. Greenland S, Senn SJ, Rothman KJ, et al. Statistical tests, P values, confidence intervals, and
314   power: a guide to misinterpretations. *Eur J Epidemiol* 2016;31(4):337-50. doi:
315   10.1007/s10654-016-0149-3 [published Online First: 2016/05/23]

316   21. Rothman KJ. Disengaging from statistical significance. *Eur J Epidemiol* 2016;31(5):443-4.
317   doi: 10.1007/s10654-016-0158-2 [published Online First: 2016/06/09]

318   22. Little R. Calibrated Bayes. *Am Stat* 2006;60(3):213-23. doi: 10.1198/000313006X117837

319   23. Hopkins WG, Batterham A. The vindication of magnitude-based inference. *Sportscience*
320   2018;22:19-29.

321   24. Little RJ. Calibrated Bayesian inference: a comment on The Vindication of Magnitude-Based
322   Inference. *Sportscience* 2018;22

323   25. Batterham AM, Hopkins WG. Making meaningful inferences about magnitudes. *Int J Sports*
324   *Physiol Perform* 2006;1(1):50-57.

325   26. Lassere MN, van der Heijde D, Johnson KR. Foundations of the minimal clinically important
326   difference for imaging. *J Rheumatol* 2001;28(4):890-1. [published Online First:
327   2001/05/01]

328   27. Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in
329   variables relevant to sports medicine. *Sports Med* 1998;26(4):217-38. [published Online
330   First: 1998/11/20]

331   28. Atkinson G. Does size matter for sports performance researchers? *J Sports Sci* 2003;21(2):73-
332   4. doi: 10.1080/0264041031000071038 [published Online First: 2003/03/13]

333   29. Akenhead R, Nassis GP. Training load and player monitoring in high-level football: current
334   practice and perceptions. *Int J Sports Physiol Perform* 2016;11(5):587-93. doi:
335   10.1123/ijspp.2015-0331 [published Online First: 2015/10/13]

336   30. Al Haddad H, Simpson BM, Buchheit M, et al. Peak match speed and maximal sprinting speed
337   in young soccer players: effect of age and playing position. *Int J Sports Physiol Perform*
338   2015;10(7):888-96. doi: 10.1123/ijspp.2014-0539 [published Online First: 2015/02/25]

339   31. Mendez-Villanueva A, Buchheit M, Simpson B, et al. Does on-field sprinting performance in
340   young soccer players depend on how fast they can run or how fast they do run? *J Strength*
341   *Cond Res* 2011;25(9):2634-8. doi: 10.1519/JSC.0b013e318201c281 [published Online
342   First: 2011/07/20]

343