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3 **Monitoring player fitness, fatigue status and running**
4 **performance during an in-season training camp in elite Gaelic**
5 **football**

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ABSTRACT

The current investigation examined selected perceptual and physiological measures to monitor fitness, fatigue and running performance during a one week in-season training camp in elite Gaelic football. Twenty-two elite Gaelic football players were monitored for training load (session RPE x duration), perceived ratings of wellness (fatigue, sleep quality, soreness); heart rate variability (HRV;LnSD1), heart rate recovery (HRR), exercise heart rate (HRex), lower limb muscular power (CMJ) and global positioning system (GPS) variables. The Yo-Yo intermittent recovery test level 1 (Yo-YoIR1) was assessed pre-and post the training camp. GPS units were used to monitor players throughout the camp period, with specific small sided games (SSG) used as a measure of running performance. There were significant day-to-day variations in training load measures (Coefficient of variation, CV: 51%; $p \leq 0.001$), HRex decreased (-12.2%), HRR increased (+10.3%) CMJ decreased (-8.1%) and pre-training LnSD1 (+14.1%) increased during the camp period. Yo-YoIR1 performance (+19.7%), total distance (TD) (+9.4%), high speed distance (HSD) (+12.1%) and sprint distance (SPD) (+5.8%) within SSG improved as the camp progressed. Δ HRex and Δ HRR were correlated with Δ Yo-YoIR1 ($r = 0.64$; -0.55), Δ HSD ($r = 0.44$; -0.58), Δ SPD ($r = 0.58$; -0.52). Δ LnSD1 was correlated with Δ Yo-YoIR1($r = 0.48$; 90%CI: 0.33 to 0.59) and Δ TD ($r = 0.71$) There were large correlations between Δ wellness and Δ Yo-YoIR1 ($r = 0.71$), Δ TD ($r = 0.68$) and Δ SPD ($r = 0.68$). Increases in training load were observed during the training camp. Daily variations in training load measures across the camp period were shown to systematically impact player's physiological, performance and wellness measures.

Keywords: GPS, HR, Team-sports, Monitoring, Training Load

INTRODUCTION

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Gaelic football is an intermittent team based field sport that can be best described as a running game that requires a combination of athleticism with skilful foot and hand passing. Players complete on average 9222 ± 1588 -m of total running distance with 18% completed at high speed (≥ 17 km·h⁻¹) across 70 min of match-play (Malone et al., 2016c; Malone, Solan & Collins 2016a). The monitoring of training load within all team sports is important for the periodisation and subsequent planning of the physical ‘dose’ during training periods (Malone & Collins, 2016; Tran et al., 2015). This is of further importance within condensed acute training periods such as in-season training camps. Within team sports (Gabbett et al., 2012; Rogalski et al., 2013; Ritchie et al., 2016) reductions in training load as the season progresses is commonplace. However, within Gaelic football previous literature has shown no changes in training load across the season (Malone et al., 2016b). The seasonal calendar is heavily focused towards the end of year All-Ireland series (Malone et al., 2016b). The All-Ireland series represents a direct knock-out style competition that takes place after the National League competition during the months of May through to September, and is considered the sports premier competition. The All-Ireland series is the key factor in the lack of variation seen in training load across the calendar within Gaelic football (Malone et al., 2016b). In order to maximise adaptations prior to the beginning of this competition teams regularly participate in an acute intensified training period during a training camp. Anecdotally, teams treat these camps as professional environments training two or three times daily with as much as 10 sessions completed during a weekly period.

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Many monitoring variables have been suggested to analyse players training load and status (Buchheit et al., 2012; Buchheit, 2014; Thorpe et al., 2015). However, their invasive and/or exhaustive nature makes their frequent assessment within team sports difficult. Non-invasive measures of assessing fitness, wellness, recovery status and physical performance have received increased interest over the last number of years (Le Meur et al., 2013; Le Meur et al., 2016). These measures of interest include, sub-maximal exercise

99 HR (HR_{ex}) and pre-exercise cardiac autonomic activity as inferred from
100 heart rate variability (HRV) measures, simply defined as the variation in the
101 beat-to-beat intervals of the heart (Le Meur et al., 2013; Le Meur et al.,
102 2016). When considering non-invasive performance assessment HR_{ex},
103 considered an index of cardiorespiratory fitness has previously been strongly
104 correlated with running performance (Buchheit et al., 2010). HRV has
105 previously been shown to be related to acute fatigue experienced by players
106 following bouts of exercise (Le Meur et al., 2013; Le Meur et al., 2016) while
107 also allowing coaches to alter the training periodization of athletes (Le Meur
108 et al., 2013; Le Meur et al., 2016). Heart rate recovery (HRR) can infer how
109 athletes are adapting to a specific training stimulus (Buchheit, 2014) and has
110 been reported to be sensitive to functional overreaching (Le Meur et al.,
111 2016). Finally, psychological monitoring is also purported to be an effective
112 means of assessing players' responses to subtle variations in training load
113 (Gallo et al., 2016; Thorpe et al., 2015; Main & Grove, 2009). However,
114 whether these variables are sensitive to acute fatigue, wellness, recovery,
115 status and in turn, fitness, during an in-season training camp within elite
116 Gaelic football players is unknown.

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118 Despite the lack of Gaelic football specific research, across team
119 sports numerous descriptive analyses of training camps have been conducted
120 (Buchheit et al., 2013; Pitchford et al., 2016; Thornton et al., 2016). Recently
121 research revealed that during a camp period training loads can increase by
122 between 50-58% when compared to normative training load values
123 (Buchheit et al., 2013; Thornton et al., 2016). Not surprisingly, during these
124 acute intensified periods, players have been found to have disturbed sleep
125 patterns and reduced wellness measures (Thornton et al., 2016). Indeed,
126 these intensified periods result in training-induced fatigue which is generally
127 associated with an increased sympathetic activity (Mourot et al., 2004) that
128 can increase sub-maximal HR and decrease HRV measures (LnSD1) within
129 players (Buchheit, 2014). Interestingly despite these acute increases in
130 training load causing the early stages of over-reaching in athletes, these camp

131 periods tend to increase players performance measures (Buchheit et al.,
132 2013).

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134 Given the lack of research conducted on camp periods in elite Gaelic
135 football, the overall purpose of the current study was to (1) examine the daily
136 variations of selected running, physiological and psychometric variables
137 during an in-season training camp in elite Gaelic football players to (2)
138 examine the usefulness of these variables in monitoring players training
139 responses during an intensified training period and (3) to assess these
140 variables association with changes in Yo-YoIR1 and standardised small
141 sided games performance during the camp period.

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143 **METHODS**

144 *Subjects*

145 The current investigation was a observational study of elite Gaelic
146 football players competing at the highest level of competition (National
147 League Division 1 and All-Ireland). Data were collected for 22 players
148 (Mean \pm SD, age: 24.3 \pm 6.1 years; height: 180.2 \pm 7.3 cm; mass: 81.6 \pm 7.5
149 kg) across a one-week training camp during the competition season. The
150 senior level playing experience of the current squad was 8.5 \pm 4.3 years. The
151 study was approved by the local institute's research ethics committee and
152 written informed consent was obtained from each participant.

153 *Training Camp*

154 The study was conducted during a one-week training camp (7-day)
155 prior to the commencement of the All-Ireland series. During the one-week
156 training camp, all players took part in an intensified team based training
157 period as prescribed by the coaches and strength and conditioning staff.
158 Players participated in 10 field based sessions (6 technical, 2 fitness and skill
159 based sessions, 2 match play sessions, total session exposure: 11.5 hr), 2
160 interval cycling sessions (10-15 maximal efforts repetitions of 5-30 seconds
161 in duration x 3-6 sets) (total session exposure: 1.5 hr) and two strength based

162 gym sessions (total session exposure: 2.5 h). All players were provided with
163 standardised post training session nutritional plan by the team's nutritionist.
164 All plans were developed and tailored to each individual athlete's needs to
165 ensure adequate fluid and nutrient intake and recovery between sessions.

166 ***Monitoring Load and Wellness***

167 The intensity of all training sessions were estimated using the
168 modified Borg CR-10 rate of perceived exertion (RPE) scale, with ratings
169 obtained from each individual player 30 min after the end of each training
170 session (Malone et al., 2016b; Fanchini et al., 2016). Each individual RPE
171 value was multiplied by the session duration to generate an arbitrary unit
172 (AU) internal training load score for the specific session (Malone et al.,
173 2016c). Additionally, a psychometric questionnaire was used to assess
174 general indicators of player wellness (Gallo et al., 2016; Thorpe et al., 2015;
175 Main & Grove, 2009). The questionnaire assessed the following elements of
176 wellness: 1) muscular soreness, 2) sleep quality, 3) fatigue, 4) stress and 5)
177 energy level, on a seven-point likert scale ranging from 1 (strongly disagree)
178 to 7 (strongly agree). The five individual wellbeing responses for a given day
179 were summed to provide a quantitative score of overall perceived wellness
180 for each player with a maximal wellbeing score of 35 arbitrary units (AU).
181 The co-efficient of variation for the five indices ranged from 5-11 % within
182 the current squad. Prior to training players completed an assessment for
183 vertical jump performance through a countermovement jump (CMJ)
184 assessment (OptoJump, Microgate, Bolzano, Italy), in which they were
185 required to perform a single CMJ. The CMJ were performed with hands held
186 firmly on the hips and subjects were instructed to jump as high as possible.
187 The jump was performed at a self-selected countermovement depth and no
188 instruction was given on what countermovement depth to use with flight time
189 used to estimate jump height (cm).

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191 ***Monitoring Fitness***

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193 A Yo-Yo Intermittent Recovery test level 1 (Yo-YoIR1) (Bangsbo et
194 al., 2008; Roe and Malone, 2016) was performed outdoors at the same time

195 of day (11:00) in temperate conditions (20°C), at the beginning (day 1) and
196 at the end (day 7) of the camp. All players were familiar with this test, as it
197 was part of the regular fitness testing battery implemented by the
198 conditioning staff. Briefly, the Yo-YoIR1 consists of repeated 20-m shuttle
199 runs at increasing speeds (starting at 8 km·h⁻¹) with 10 s of active recovery
200 (consisting of 5-m of jogging) between runs, until exhaustion. A sub-
201 maximal 5-min running/5-min recovery test (Buchheit et al., 2013; Buchheit
202 et al., 2010) was performed at the start of every training/testing session to
203 assess training status. All players were tested simultaneously with the
204 intensity of the exercise bout fixed at 13 km·h⁻¹ over 40-m shuttles. HR_{ex}
205 and post exercise heart rate recovery (HRR) for a 1 min period were recorded
206 during the assessment (Le Meur et al., 2016). Prior to all training HRV
207 (standard deviation of instantaneous beat-to-beat R–R interval variability)
208 was measured by all players using a provided HR strap (Polar Team 2
209 system; 1.4.1, Polar Electro Oy, Kempele, Finland). Specifically, in a room
210 by themselves prior to training, players were instructed to remain in a supine
211 position for 8 min. R-R intervals were recorded and analysed during the last
212 4 min of the supine position (Le Meur et al., 2013).

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214 ***Monitoring Running Performance***

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216 During all outdoor training sessions' players were monitored using
217 GPS units (18-Hz, GPEXE LT, Exelio, Udine, Italy). Sport-specific running
218 performance was assessed using specific small-sided games (SSG) that were
219 completed every day during the camp as the first main drill of training. The
220 specific SSG was a 4v4 - 60x20-m - touchdown drill (Malone, Solan &
221 Collins, 2016a), where the aim of the drill was for teams to keep possession
222 of the ball and attack an end zone area. Once a team had moved the ball into
223 the end zone area they retain possession of the ball and aimed to move the
224 ball back down into the opposite end zone. Total (TD); high-speed (HSD,
225 ≥ 17 km·h⁻¹), sprint (SPD; ≥ 22 km·h⁻¹) distance as well as maximal velocity
226 (km·h⁻¹) were evaluated during all training sessions. Training data was
227 analysed post session with retrospective analysis conducted on all sessions.
228 Each file was then trimmed so only data recorded during each session and

229 specifically each drill when the player was on the field was included for
230 further analysis. Data were exported into a customised spreadsheet (Excel,
231 Microsoft Redmond, USA). This spreadsheet allowed for the analysis of
232 distance covered in the following categories: total distance (TD; m); high
233 speed running ($\geq 17 \text{ km}\cdot\text{h}^{-1}$, HSD; m), sprint distance ($\geq 22 \text{ km}\cdot\text{h}^{-1}$; SPD; m),
234 and maximal velocity ($\text{km}\cdot\text{h}^{-1}$).

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236 *Statistical Analysis*

237 Data are presented as means (\pm SD) and correlations as means (90%
238 confidence limits, CL). The distribution of each variable was examined with
239 the Kolmogorov–Smirnov normality test. Prior to analysis, all data were log
240 transformed to reduce the error occurring from non-uniform residuals
241 (heteroscedasticity) that occurs with all measures of athletic performance. A
242 one-way repeated measures ANOVA with a Bonferroni’s post hoc tests was
243 used to assess changes in TL, fitness, fatigue/wellness, CMJ and running
244 performance measures throughout the camp period. Furthermore, the change
245 in variables throughout the camp was also assessed using within-individual
246 regression analysis (%/day, with 90% CL). Pearson’s correlation analysis
247 was used to assess the associations between within-player daily changes in
248 TL, fitness, fatigue/wellness and running performance measures. To account
249 for the effect of fatigue/wellness on changes in running performance, these
250 relationships were adjusted to reflect any changes in fitness measures (HRex;
251 HRR; LnSD1) with partial correlations. The following criteria were used to
252 interpret the magnitude of the correlation (r) between the different measures:
253 ≤ 0.1 , trivial; $>0.1–0.3$, small; $>0.3–0.5$, moderate; $>0.5–0.7$, large; $>0.7–0.9$,
254 very large; and $>0.9–1.0$, almost perfect. If the 90% CL overlapped positive
255 and negative values, the magnitude was deemed unclear (Hopkins et al.,
256 2009). Statistical analyses were performed using SPSS for Windows
257 (Version 22, SPSS Inc. Chicago, IL, USA) with statistical significance set at
258 an accepted level of $p < 0.05$.

259

260 **RESULTS**

261 During the camp period players completed on average a TD of 54175
262 ± 4254 -m with 9244 ± 2254 -m of HSD and 1678 ± 554 -m of SPD. Players
263 completed twelve training sessions across a seven-day camp period with a
264 training load (AU) of 5984 ± 554 AU. Changes in training load and status
265 measures are shown in Figure 1 with changes in wellness and status measures
266 shown in Figure 2. There were significant day-to-day variations in training
267 load measures (Co-efficient of variation, CV: 51%; $p \leq 0.001$). All wellness
268 measures (CV: 9-25%; $p \leq 0.004$ for all), TD (CV: 8-11%; $p = 0.04$), HSD
269 (CV: 9-59%; $p = 0.001$), SPD (CV: 10-68%; $p = 0.001$) varied from day-to-
270 day. With regard to player wellness this fluctuated throughout the camp but
271 did not substantially change from the start to end of the camp. However,
272 HRex decreased (-12.2%; 90%CI: - 5.1 to - 13.4%), HRR increased
273 (+10.3%; 90%CI: 9.1 to 15.3%), CMJ decreased (-8.1%; 90%CI: - 4.2 to -
274 10.1%), and pre-training LnSD1 (+14.1%; 90%CI: 8.1 to 17.5%) increased
275 during the camp period. Yo-YoIR1 performance (+19.7%; 90%CI: 15.2-
276 23.7%), TD (+9.4%; 90%CI: 8.3-15.1%), HSD (+12.1%; 90%CI: 5.9-14.2)
277 and SPD (+5.8%; 90%CI: 3.3-7.9) within SSG, improved as the camp
278 progressed (Figure 2). The Δ LnSD1, Δ sleep and Δ soreness were largely
279 correlated ($r = -0.63$; -0.63 ; -0.54). Similarly, the Δ HRR correlated largely
280 with Δ sleep ($r = -0.54$; 90%CI: -0.52 to -0.64). Δ LnSD1, Δ sleep, Δ soreness
281 and Δ HRex were associated with training load (Figure 4). Δ HRex was
282 moderately correlated to Δ wellness ($r = -0.38$; 90%CI: -0.22 to -0.55). Table
283 1 shows the correlates of performance during the training camp, Δ HRex and
284 Δ HRR were correlated with Δ Yo-YoIR1 ($r = 0.64$; - 0.55), Δ HSD ($r = 0.44$;
285 -0.58), Δ SPD ($r = 0.58$; -0.52) but not Δ TD during SSG. Δ LnSD1 was
286 correlated with Δ Yo-YoIR1($r = 0.48$; 90%CI: 0.33 to 0.71) and Δ TD ($r =$
287 0.71; 90%CI: 0.55 to 0.87) but not with any other running performance
288 measures during SSG. There were large correlations between Δ wellness and
289 Δ Yo-YoIR1 ($r = 0.71$; 90%CI: 0.55 to 0.87), Δ TD ($r = 0.68$; 90%CI 0.45 to
290 0.66) and Δ HSD ($r = 0.68$; 90%CI: 0.53 to 0.77) but not Δ SPD ($r = 0.17$;
291 90%CI: 0.05 to 0.22).

292

293 **DISCUSSION**

294 The aim of the current investigation was to examine selected
295 movement, physiological and perceptual measures to monitor fitness, fatigue
296 and running performance during an in-season training camp in elite Gaelic
297 football players. The main findings of the current study were (1) that running
298 performance during SSG and Yo-YoIR1 performance increased throughout
299 the camp period. (2) Heart rate (HRR, HRex, LnSD1), all wellness and
300 vertical jump performance (CMJ) measures were shown to respond to subtle
301 daily changes in training load during the period. (3) Changes in heart rate
302 measures were correlated to changes in player wellness during the camp. (4)
303 Changes in wellness and heart rate measures were correlated to changes in
304 Yo-YoIR1 performance in addition to running performance during
305 standardised SSG during the camp.

306 Our results show that during the one-week training camp players
307 completed on average loads of 5984 ± 554 AU across twelve training
308 sessions (Figure 1). The current workloads are higher than previously
309 reported within Gaelic football (2560-2740 AU) (Malone et al., 2016b).
310 Interestingly, within the current weekly period loads were 42-45% higher on
311 average, however, this is not surprising and agrees with research conducted
312 during many other training camp periods in team sports (Buchheit et al.,
313 2013; Thornton et al., 2016). Coaches should be aware that sudden increases
314 or “spikes” in load have been linked to increased risk of injury within Gaelic
315 football (Malone et al., 2016b; Malone et al., 2016c) and other team sport
316 cohorts (Cross et al., 2016; Malone et al., 2016a). Therefore, coaches need
317 to plan for these in-season camp periods ensuring that players’ previous
318 loading prior to the camp period is appropriate in order to best moderate the
319 risk associated with the increased training demand placed on players during
320 these training camp periods (Malone et al., 2016b; Malone et al., 2016c).
321 Furthermore, and in contrast to previous literature where spikes in load have
322 been linked to injury risk (Malone et al., 2016a; Cross et al., 2016; Malone
323 et al., 2016b), in the current study, no injuries were suffered by players
324 monitored for the whole duration of the camp, this may be related to the
325 reduction in overall maximal velocity and lower limb power capabilities of
326 players which may have reduced the overall intensity of training sessions.

327 During the camp, player's wellness measures did not significantly
328 decrease from the start to the end. Moreover, when LnSD1 and HRR were
329 considered as a cardiac autonomic marker of physiological stress throughout
330 the period, we observed an increase across the aforementioned period (Figure
331 1). Previous studies have suggested that LnSD1 and HRR should decrease in
332 the presence of fatigue and physiological stress. However, recently several
333 studies have shown that in the presence of systematic increases in training
334 load that a down-regulation of the sympathetic nervous system and/or
335 changes in the balance between parasympathetic and sympathetic tone can
336 occur. The down-regulation can result in increased pre-exercise LnSD1 and
337 post-exercise HRR responses, this has been partly linked to an increase in
338 parasympathetic modulation of HR during the overload period (Le Meur et
339 al., 2016; Buchheit, 2014; Le Meur et al., 2013). Therefore, practitioners
340 should be aware that the utilisation of a single measure of physiological
341 training would not be recommended to monitor responses to intensified
342 training load periods in team sports such as Gaelic football. We therefore
343 suggest a holistic approach to monitoring responses to intensified periods of
344 training where a number of measures are utilised by practitioners in order to
345 modify and adjust players training load to ensure players are in a non-
346 fatigued state prior to competition.

347 During the current camp period TD, HSD and SPD improved during a
348 standardized SSG with improved Yo-YoIR1 performance during the camp
349 period (Figure 3). While a lack of a control group prevents definitive
350 conclusions to be made about the acute intensified training period, these
351 results may provide efficacy for such a camp to improve running and
352 physical performance characteristics of elite Gaelic football players. These
353 results have direct implications for Gaelic football coaches who are
354 searching for the most prudent training strategies to apply during in-season
355 training camps. The improvement in running performance during
356 performance tests such as Yo-YoIR1 can be related to general training-
357 induced improvements in fitness and wellness. Furthermore, the
358 improvements in SSG running performance may be related to the increase in
359 aerobic fitness during the training camp. However, familiarisation with the

360 drill type as the camp progressed may be considered as a potential impacting
361 factor within the current results, however future literature needs to
362 investigate this in greater detail to confirm the authors hypothesis (Figure 3).
363 Moreover, moderate to very-large correlations between heart rate training
364 load variables (HR_{ex}, HRR, LnSD1) and changes in SSG running and Yo-
365 YoIR1 performance were observed. These findings are in agreement with
366 previous training camp investigations (Buchheit et al., 2013). These findings
367 add support to the utilisation of simple, non-invasive and non-fatiguing
368 measures for monitoring training responses in elite team sport athletes.
369 Interestingly, the current study found a linear increase in standardised SSG
370 running performance across the duration of the training camp. Although the
371 magnitude of increase for these running based variables was lower than that
372 observed in Yo-YoIR1 performance. Additionally, the correlations between
373 changes in running and HR measures was lower than that of Yo-YoIR1. We
374 suggest that standardised SSG may provide an insight into potential acute
375 changes in physical performance of team sport players. We suggest that
376 future studies in Gaelic football assess the application of standardised SSG
377 as a potential running performance test during training periods. However, we
378 acknowledge that a stringent prediction of changes to physical performance
379 characteristics during standardised SSG from physiological and running
380 measures is more difficult than in standardised testing protocols such as the
381 Yo-YoIR1.

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383 Significant daily variations in training load (sRPE) across the camp
384 period were observed and these measures were shown to systematically
385 impact player's physiological response, psychological wellness and running
386 performance for the following day. The current findings have significant
387 implications for Gaelic football coaches highlighting the importance of
388 systematic monitoring of players. Additionally, both negative and positive
389 correlations between these daily fluctuations in training load variables and
390 changes in load measures were found. The negative association between
391 changes in training load and wellness measures was expected. Interestingly,
392 we observed that increases in training load were positively related to changes
393 in HRR and LnSD1 (i.e. increases in acute load resulted in increased HR

394 responses). These results may be related to acute training load fatigue which
395 may have resulted in a modulation of HR responses and reduced player's
396 sympathetic activity (Le Meur et al., 2013; Le Meur et al., 2016).

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398 The findings within the current investigation provide evidence
399 supporting the sensitivity of simplistic monitoring measures to detect acute
400 fluctuations in training load. Moreover, the findings show that the collection
401 of training load data within Gaelic football players even when considered
402 across an acute period (7 days) can provide meaningful indirect information
403 about player's responses and status to fluctuations in training load the
404 following day. Interestingly we found significant reductions in self-reported
405 sleep quality of players throughout the camp period (Figure 2). The finding
406 agrees with previous investigations in rugby league (Thornton et al., 2016)
407 and Australian Rules cohorts (Buchheit et al., 2013; Pitchford et al., 2016),
408 that reported reductions in sleep efficiency and the onset of sleep during
409 training camp periods when contrast to home based training periods. The
410 addition of our findings to this previously published research demonstrates
411 that sleep quality is jeopardized during training camps (Pitchford et al.,
412 2016). We suggest that Gaelic football coaches' prioritise periods of planned
413 sleep such as naps for players during these camp periods to reduce the effects
414 of acute fatigue. Previous studies (Thornton et al., 2016) reported that when
415 athletes adhered to napping recommendations during a training camp, there
416 were benefits in recovery and subsequent night time sleep quality. Optimal
417 quality and quantity of sleep would seem beneficial given its established role
418 in facilitating athletic recovery and performance (Pitchford et al., 2016;
419 Thornton et al., 2016). Indeed, improving sleep quality within basketball
420 players improved sprint time, free throw accuracy, reaction time and ratings
421 of physical and wellness (Mah et al., 2011). Theoretically, maximising sleep
422 time and quality during a period of high training stress may accentuate
423 training recovery and adaptations (Pitchford et al., 2016; Thornton et al.,
424 2016).

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426 The findings of the current paper need to be considered with several
427 limitations. Firstly, since training sessions with different contents were

428 carried out during the training camp, it is difficult to determine whether the
429 whole training camp or only some of the training sessions were responsible
430 for the induced changes in the measured variables. Furthermore, the
431 investigation failed to provide a control group to compare a similar period of
432 intensified training to in order to determine if the findings are consistent
433 across similar cohorts and time frames. Future research should examine in
434 detail the changes in both training load characteristics and wellness profiles
435 of Gaelic footballers from home to camp periods. This will allow coaches to
436 best prepare players for the increased training loads experienced during camp
437 periods. Additionally, although no injuries were suffered by players during
438 the current camp, future research should aim to provide an analysis of a post
439 camp periods and account for any injuries or illnesses suffered by players
440 following the training camp. This will facilitate optimal planning post the
441 intensified period of training. Finally, with the observed reduction in sleep
442 quality throughout the 7-day camp period it is important for research to
443 examine the individual sleep responses to training load during a season but
444 also within acute intensified periods of training.

445

446 **CONCLUSION**

447 The current camp resulted in a 42-45% increase in training load. Daily
448 variations in training load measures across the camp period were shown to
449 have a fluctuating impact player's physiological, performance and wellness
450 measures from day-to-day. During the current camp period running
451 performance measures were shown to improve during a standardized SSG
452 with improved Yo-YoIR1 performance during the camp period. When
453 considering the association between changes in running performance and
454 changes in training load variables moderate to very-large correlations
455 between heart rate variables, wellness and changes in sport specific running
456 and YoYoIR1 performance were shown. Overall the study highlights the
457 need to systematically monitor players while adding further credence to the
458 application of simple, non-invasive and non-fatiguing measures for
459 monitoring training responses in elite team sport athletes.

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PRACTICAL APPLICATIONS

- During the training camp periods heart rate (HRR, HRex, LnSD1), all wellness and vertical jump performance (CMJ) measures may be used by practitioners during training camps to identify positive and negative responses during training camp periods.
- Changes in heart rate measures were correlated to changes in player wellness, while both measures were related to changes in running performance and aerobic fitness. It may be suggested that one of these monitoring variables be used during a training camp period given the high levels of correlation.
- Monitoring high speed and sprint running distance on a day-by-day basis (e.g. GPS measures) is valuable to confirm the potential transfers from sport-specific training (SSG) to physical running performance (Yo-YoIR1) within camp settings.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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639 **FIGURE CAPTIONS**

640

641 **Figure 1** - Daily changes in (A) total distance (m) - double bars indicate completion of two
642 sessions on the given day, (B) training load (sRPE; AU) - double bars indicate completion of
643 two sessions on the given day, (C) sub-maximal exercise heart rate (HR_{ex}) and Heart rate
644 recovery (HRR), (D) natural logarithm of standard deviation of instantaneous beat-to-beat R–
645 R interval variability, measured from Poincaré plots prior to the completion of training
646 (LnSD1). All data presented as mean ± SD.

647

648 **Figure 2** - Daily changes in (A) wellness (AU), (B) sleep quality (AU) (C) counter-
649 movement jump (cm) (D) maximal velocity (km·h⁻¹) (E) fatigue (F) stress. All data presented
650 as mean ± SD.

651

652 **Figure 3** - Running performance changes during and after the camp as measured by total
653 distance during the Yo-Yo Intermittent Recovery Level 1 (Yo-YoIR1) and total (TD) and
654 high-speed (HSD) and sprint (SPD) distance during standardized small sided games (SSG).

655

656 **Figure 4** - Correlation coefficients (90% confidence intervals, CI) between daily (i.e. session-
657 to-session) changes in training load (Δ TL) and daily (i.e. session-to-session) changes in sub-
658 maximal exercise heart rate (Δ HR_{ex}), heart rate recovery (Δ HRR), natural logarithm of
659 standard deviation of instantaneous beat-to-beat R–R interval variability, measured from
660 Poincaré plots prior to training (Δ LnSD1), perceived fatigue (Δ Fatigue), sleep quality (Δ Sleep),
661 muscle soreness (Δ Soreness), stress (Δ Stress), energy (Δ energy) during the training camp.

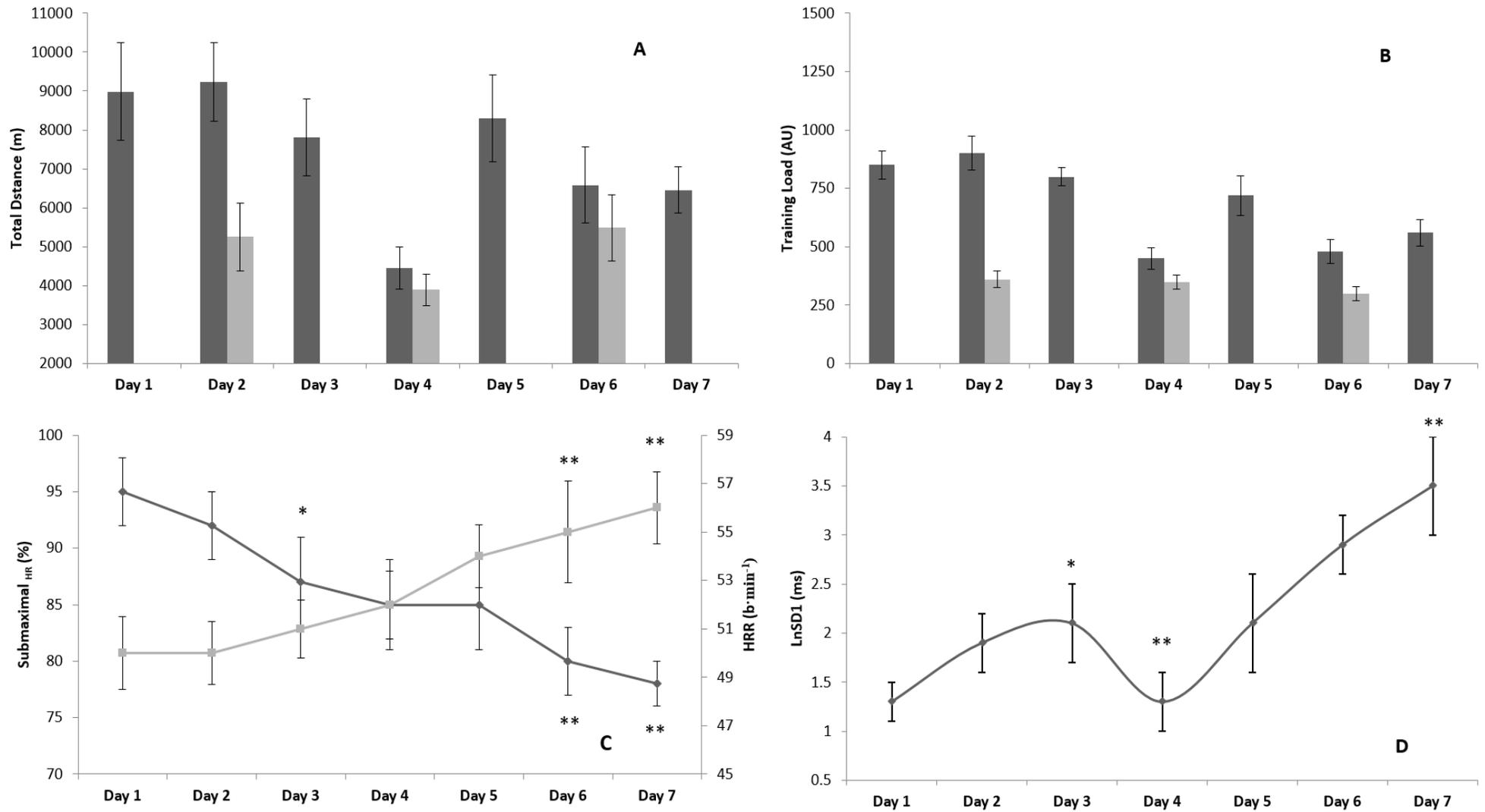
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663 **TABLE CAPTIONS**

664

665 **Table 1** - The correlation coefficients (90% CI) between daily individual changes in sub-
666 maximal exercise heart rate (Δ HR_{ex}), heart rate recovery (Δ HRR), natural logarithm of standard
667 deviation of instantaneous beat-to-beat R–R interval variability, measured from Poincaré plots
668 prior to training (Δ LnSD1), overall wellness (Δ Wellness) and running performance changes
669 during and after the camp as measured by total distance during the Yo-Yo Intermittent
670 Recovery Level 1 (Yo-YoIR1) performed outdoor and total distance, high-speed distance
671 (HSD) and sprint (SPD) distance during standardized SSG performed outdoor.

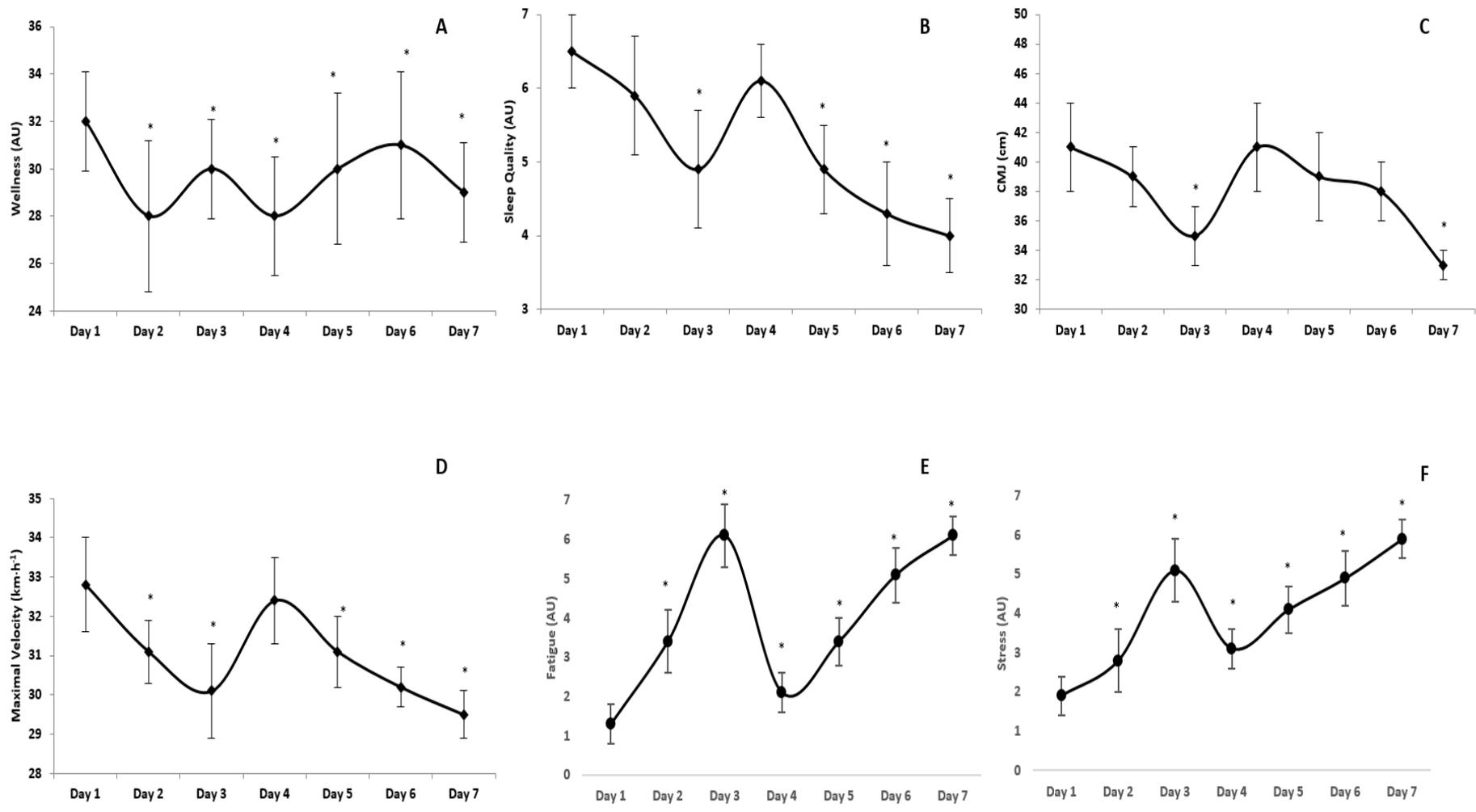
672 **Figure 1**



673
674 *Significant difference vs. day one with $P < 0.05$. **Significant difference vs. day one with $P < 0.01$

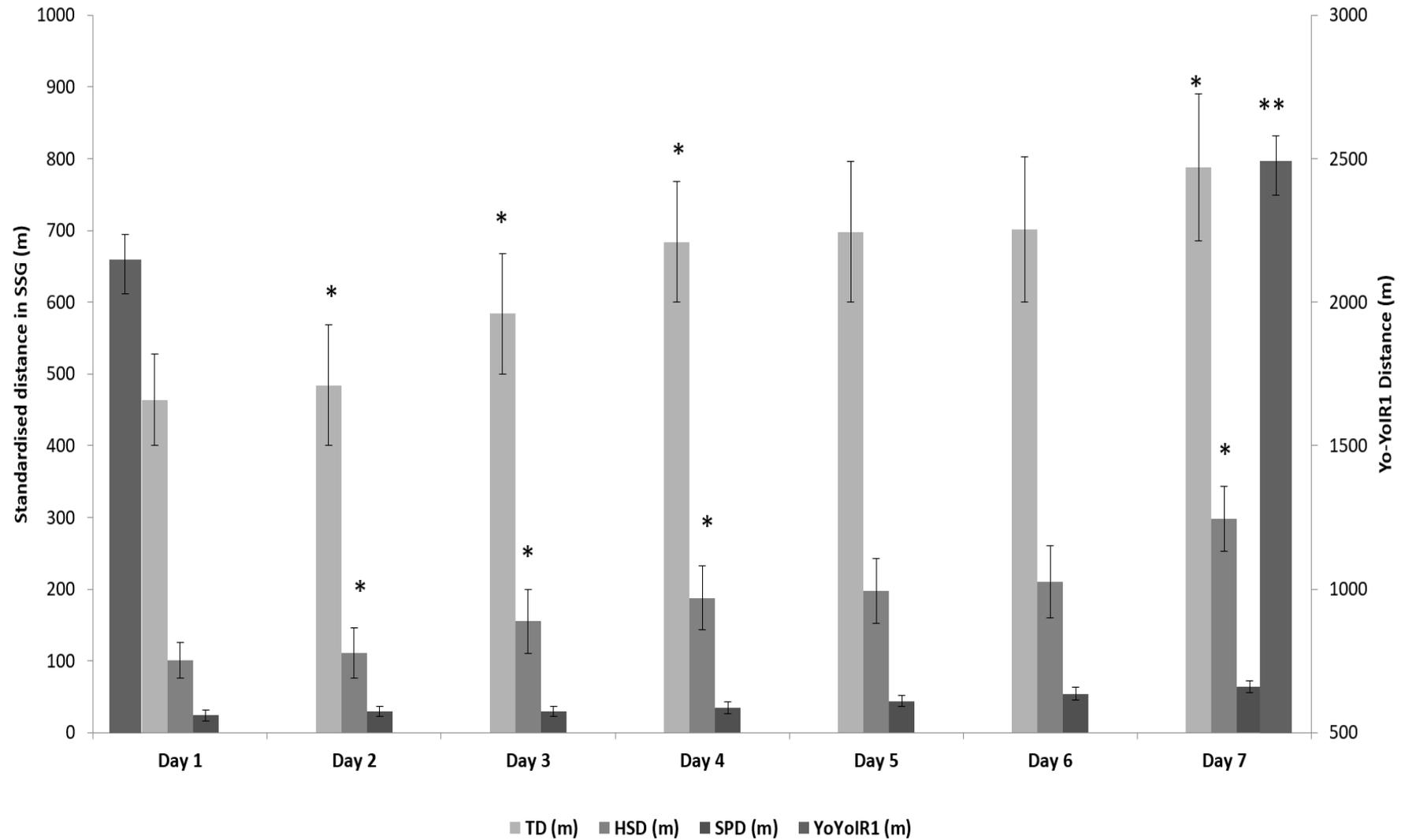
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676 **Figure 2**



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 678 *Significant difference vs. day one with $P < 0.05$.
 679

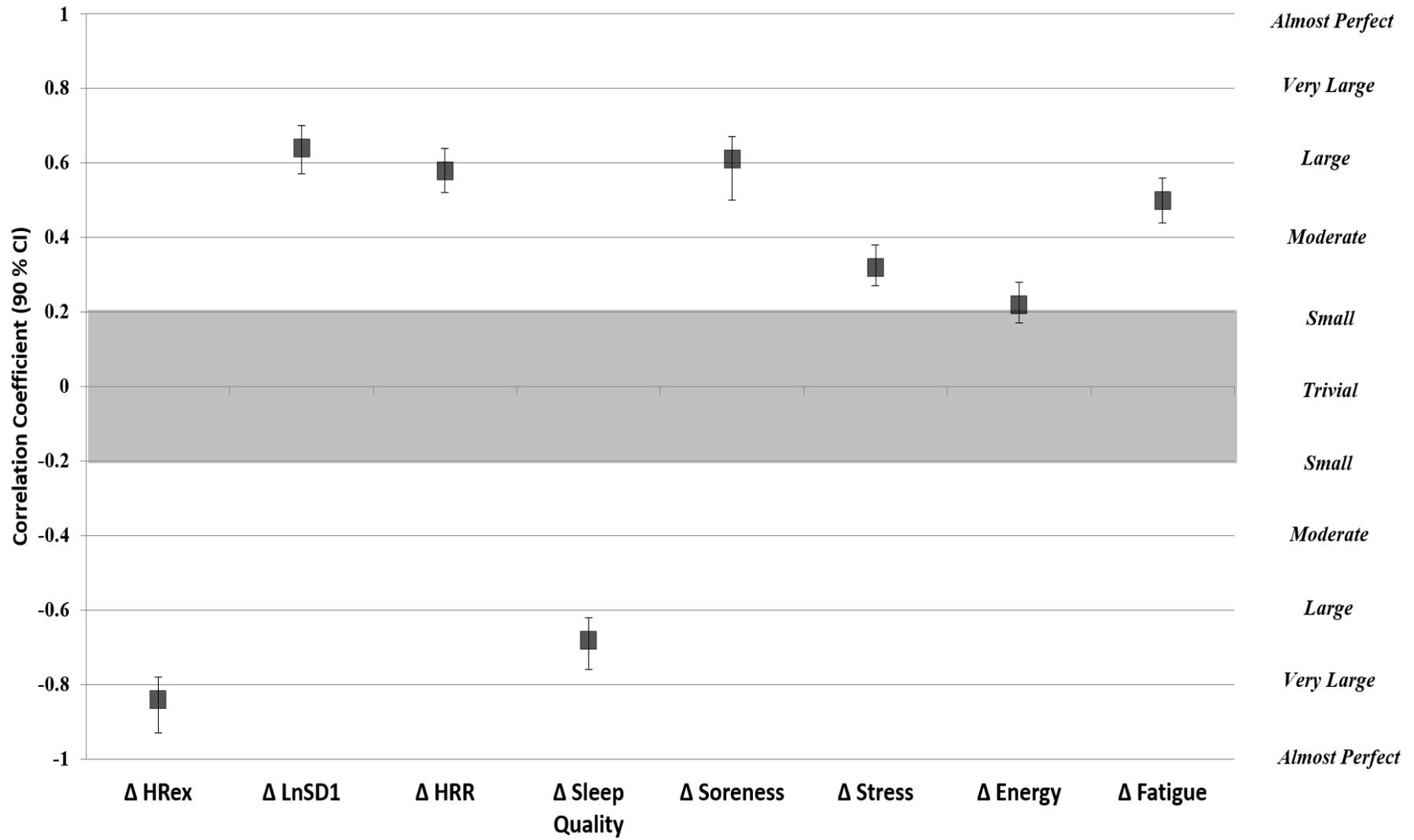
680 **Figure 3**



681

682 *Significant difference vs. initial day of SSG with $P < 0.01$. **Significant difference vs. initial test with $P < 0.001$.

683 **Figure 4**



685 **Table 1**

686

	ΔLnSD1	ΔHRR	$\Delta \text{HR}_{\text{ex}}$	$\Delta \text{Wellness}$
Yo-YoIR1 (m)	0.48 (0.33 to 0.71) **	-0.55 (-0.33 to -0.71) *	0.64 (0.44 to 0.78) **	0.71 (0.55 to 0.87) **
TD (m)	0.71 (0.55 to 0.87) **	-0.10 (-0.25 to -0.05)	0.20 (0.11 to 0.38)	0.68 (0.45 to 0.66) **
HSD (m)	0.19 (0.09 to 0.29)	-0.58 (-0.32 to -0.78) *	0.44 (0.11 to 0.65) *	0.17 (0.05 to 0.22)
SPD (m)	0.22 (0.12 to 0.32)	-0.52 (-0.33 to -0.76) *	0.58 (0.33 to 0.66)	0.68 (0.53 to 0.77) **

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