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1 **The effect of individualised sprint training in elite**  
2 **female team sport athletes: A pilot study**

3 *Individualised sprint training*

4

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6

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12

13 **Keywords:** physical training; physical performance; acceleration; horizontal power  
14 production, handball.

15

16 **Abstract**

17 This study aimed to evaluate whether an individualised sprint-training program was  
18 more effective in improving sprint performance in elite team-sport players compared  
19 to a generalised sprint-training program. Seventeen elite female handball players (23  
20  $\pm 3$  y,  $177 \pm 7$  cm,  $73 \pm 6$  kg) performed two weekly sprint training sessions over eight  
21 weeks in addition to their regular handball practice. An individualised training group  
22 (ITG,  $n = 9$ ) performed a targeted sprint-training program based on their horizontal  
23 force-velocity profile from the pre-training test. Within ITG, players displaying the  
24 lowest, highest and mid-level force-velocity slope values relative to body mass were  
25 assigned to a resisted, an assisted or a mixed sprint-training program (resisted sprinting  
26 in the first half and assisted sprinting in the second half of the intervention period),  
27 respectively. A control group (CG,  $n = 8$ ) performed a generalised sprint-training  
28 program. Both groups improved 30-m sprint performance by  $\sim 1\%$  (small effect) and  
29 maximal velocity sprinting by  $\sim 2\%$  (moderate effect). Trivial or small effect  
30 magnitudes were observed for mechanical outputs related to horizontal force- or power  
31 production. All between-group differences were trivial. In conclusion, individualised  
32 sprint-training was no more effective in improving sprint performance than a  
33 generalised sprint-training program.

34

35

## 36 **Introduction**

37 Accelerated sprinting is a fundamental part of the motor skill requirements in team  
38 sports to win duels, defend or create goal-scoring opportunities. Sprint performance  
39 becomes more resistant to training enhancement with increasing performance level,  
40 age and training status (Vescovi, Rupf, Brown, & Marques, 2011; Haugen, Tønnessen,  
41 & Seiler, 2012 and 2013; Tønnessen, Svendsen, Olsen, Guttormsen, & Haugen, 2015).  
42 However, previous studies have shown that professional players are generally faster  
43 than semi-professional and amateur players, and professional players have become  
44 faster over time, indicating that the importance of well-developed sprinting skills has  
45 increased in modern team sports (Haugen et al., 2012 and 2013; Haugen, Tønnessen,  
46 Hisdal, & Seiler, 2014). Previously published intervention studies have typically been  
47 performed on young and/or amateur players and limited to investigating whether  
48 certain training methods are more effective than others. Although the principle of  
49 specificity is clearly present, assisted or resisted sprint training have so far not provided  
50 superior effects on accelerated sprinting capability in team sport players compared to  
51 sprinting under normal conditions (Haugen et al., 2014; Petrakos, Morin, & Egan,  
52 2016; Rumpf, Lockie, Cronin, & Jalilvand, 2016).

53 An increasing number of studies pay attention to underlying mechanical determinants  
54 for sprint performance, as such variables provide insights into individual  
55 biomechanical limitations (Morin et al., 2012; Buchheit et al., 2014; Rabita et al.,  
56 2015). Recently, a French research group presented a field method to calculate  
57 mechanical outputs and develop horizontal profiles of accelerated sprinting (Samozino  
58 et al., 2016; Morin & Samozino, 2016). Theoretical maximal velocity ( $V_0$ ), horizontal  
59 force ( $F_0$ ), horizontal power ( $P_0$ ) and force-velocity profile can be calculated from the  
60 modelling by derivation of the speed-time curve that leads to horizontal acceleration

61 data. The promising aspect of this approach is an individualised diagnosing and  
62 development of training programs that target the major limiting factors (Morin &  
63 Samozino, 2016). It has recently been reported that an individualised training program  
64 based on vertical force-velocity profiling was more effective in improving jumping  
65 performance than traditional strength/power training common to all participants  
66 (Jiménez-Reyes, Samozino, Brughelli, & Morin, 2017<sup>A</sup>; Jiménez-Reyes et al., 2017<sup>B</sup>).  
67 A similar approach based on horizontal force-velocity profiling remains to be explored  
68 for sprint running performance purposes. This can be achieved by comparing the  
69 relative strengths and weaknesses in each player's profile to the rest of the team (Morin  
70 & Samozino, 2016). Accordingly, athletes with horizontal force deficits should be  
71 given more horizontal strength work (e.g., resisted sprint), while athletes with velocity  
72 deficits should prioritize maximal velocity sprinting (e.g., assisted sprinting).

73 Therefore, the aim of the current study was to evaluate whether an individualised  
74 training program based on horizontal force-velocity profiling was more effective on  
75 accelerated and maximal velocity sprinting performance in elite team sport players  
76 compared to a generalised sprint-training program. We hypothesised that  
77 individualised sprint training would provide better effects on accelerated and maximal  
78 velocity sprinting performance.

79

## 80 **Methods**

### 81 *Design*

82 In this randomised controlled trial, participants (n=21) were allocated pairwise  
83 according to their horizontal force-velocity profile (force-velocity slope relative to  
84 body mass) from pre-training tests and then randomly assigned to one of two treatment  
85 conditions. The randomisation process was performed by a co-author not directly

86 involved in testing or the training intervention. The individualised training group (ITG,  
87 n=11) performed a targeted and individualised sprint-training program, while the  
88 control group (CG, n=10) performed a generalised sprint-training program that was  
89 the same for all the participants. Three subgroups within ITG were established. Here,  
90 the players displaying the lowest, highest and mid-level force-velocity slope values  
91 relative to body mass were assigned to a resisted (ITG<sub>1</sub> = 3), an assisted (overspeed)  
92 (ITG<sub>2</sub> = 4) and a mixed sprint-training program (ITG<sub>3</sub> = 4) (resisted sprinting in the  
93 first half and assisted sprinting in the second half of the intervention period),  
94 respectively (Figure 1). The intervention included sprint training twice a week for an  
95 8-week period for both groups. Participants were required to complete at least 14 out  
96 of 16 intervention-training sessions (87.5%) and all pre- and post-training tests in order  
97 to be included. Both ITG and CG completed, on average, 93% of the total sprint  
98 training sessions. Session rating of perceived exertion (session RPE) and perceived  
99 recovery status (PRS) were registered throughout the intervention period based on  
100 previously published guidelines (Foster, 2001; Laurent et al., 2011).

101

102 \*\*\*Figure 1 about here\*\*\*

103

#### 104 ***Participants***

105 Twenty-one professional or semi-professional female handball players in the national  
106 upper league volunteered to participate and underwent the pre-training tests. Four  
107 players dropped out immediately prior to or during the intervention, including one  
108 (from CG) who sustained a hamstring injury during one of the sprint training sessions.  
109 Overall, 17 participants completed the study with the following sample sizes: ITG = 9  
110 (age  $23 \pm 3$  y, height  $177 \pm 7$  cm, body mass  $73 \pm 6$  kg) and CG = 8 (age  $23 \pm 3$  y,

111 height  $176 \pm 6$  cm, body mass  $72 \pm 5$  kg). Training characteristics for both groups are  
112 presented in Table 1.

113 \*\*\*Table 1 about here\*\*\*

114

115 Each participant had a minimum of 10 years of handball-specific training experience.  
116 Four of the participants played for the national team while eleven players participated  
117 in the Champions League tournament during the current season. During the  
118 intervention period, participants were requested to refrain from performing any other  
119 heavy and/or high intensity off-field physical training regimes in the form of maximum  
120 strength training, high-intensity interval running or plyometric training. Regular  
121 handball training sessions typically commenced with warm-up activities like running  
122 in different directions and specific warm-up for upper and lower extremities, followed  
123 by progressive passing drills and goalkeeper warm-up. The main part of the handball  
124 practices during this period consisted of tactical-oriented and match-preparing sessions  
125 with low to moderate intensity.

126 The study was reviewed by the Regional Ethics Committee and approved by the  
127 Norwegian Data Protection Authority. All subjects signed an informed consent form  
128 before the study and were made aware that they could withdraw at any point without  
129 providing an explanation. The study was conducted in accordance with the Declaration  
130 of Helsinki.

131

### 132 *Testing procedures*

133 The pre- and post-training tests were conducted in the same handball arena. All  
134 participants completed the tests in the same order and at the same time of day.  
135 Regarding nutrition, hydration, sleep and physical activity, participants were

136 instructed to prepare as they would for a regular handball match, including no high-  
137 intensity training the last day prior to testing. They were also instructed to use identical  
138 footwear and kit for each of the tests. All participants were familiarised with sprint  
139 testing. Body mass was assessed half an hour prior to testing on each testing day.  
140 Participants then completed a 20 min standardised warm-up consisting of a general  
141 warm-up (jogging at ~60-75% of age-predicted maximal heart rate), "local" muscle  
142 warm-up (lunges, hip lift, ballistic hamstring- and hip mobility in supine and prone),  
143 specific running drills (high knees skipping, butt-kicks, straight leg pulls) and finally  
144 3-4 runs over 30-40 m with progressively increasing speed.

145 After the warm-up, participants completed two maximal 30-m sprints. Best 30-m  
146 time was included for analysis. Recovery time between trials was 3-4 min. All sprints  
147 were commenced from a standing split stance position with the toe of the front foot  
148 placed at the start line. After a ready signal was given by the test operator, athletes  
149 started on their own initiative. Musclelab (Ergotest AS, Porsgrunn, Norway) timing  
150 system was used for sprint performance assessments. An infrared contact mat  
151 covered the start line. Timing was initiated by the infrared contact at the time of front  
152 foot lift-off. Post-processing timing gates were placed at 5,10,15,20 and 30 m (120  
153 cm above floor level), and the start of the longest photocell break was used as a  
154 trigger criterion (the torso will always produce a longer break than an arm). The  
155 present timing setup provided sufficient data points for mechanical output  
156 computations (Samozino et al., 2016; Morin & Samozino, 2016) performed by a  
157 purpose-built software integrated in the Musclelab system. Typical error (TE) and  
158 coefficient of variation (CV) were 0.03 s and 1.0% for 0-30 m sprint time, 0.08 m·s<sup>-1</sup>  
159 and 1.4% for V<sub>0</sub>, 20 W and 2.6% for P<sub>0</sub>, 0.30 W·kg<sup>-1</sup> and 2.7% for P<sub>0</sub>·kg<sup>-1</sup>, 10 N and



160 2.7% for F0,  $0.14 \text{ N}\cdot\text{kg}^{-1}$  and 2.7% for F0·kg<sup>-1</sup>, and  $1.7 (\text{N}\cdot(\text{m}\cdot\text{s}^{-1})^{-1})$  and 3.4% for FV  
161 slope, based on sprint trial 1 and 2 from the pre-training tests.

162

### 163 *Intervention*

164 The sprint training intervention took place from the middle of January to the middle  
165 of March, corresponding to the late middle of the handball season for the participants.  
166 All sprint-training sessions were supervised and completed at the same time of day for  
167 both groups during the entire intervention. There was a minimum of 48 h between each  
168 sprint-training session. Identical warm-up procedures as for the pre-and post-training  
169 tests were performed prior to each sprint training. The intervention protocol was  
170 periodised with a gradual increase in the number of weekly-performed sprints during  
171 the first half of the intervention, followed by a corresponding decrease in sprint  
172 repetitions (for tapering purposes) the last three weeks prior to the post-training test  
173 (Table 2). Each sprint training session followed a stepwise change (increase/decrease)  
174 in resistance/assistance, to ensure a gradual and smooth progression. The number of  
175 sprints was equal for all participants during all sprint-training sessions, and recovery  
176 between each sprint was 3-4 min. The players were encouraged to perform all sprints  
177 with maximal effort.

178

179 \*\*\*Table 2 about here\*\*\*

180

181 CG performed 30-m sprints (sprinting under normal conditions, no assistance or  
182 resistance) during the entire intervention. 1080 Sprint (1080 Motion AB, Stockholm,  
183 Sweden), a portable resistance/overspeed training device that uses a servo motor (2000  
184 RPM OMRON G5 Series Motor, OMRON Corporation, Kyoto, Japan), was used by  
185 ITG during all sprint sessions. The cord from the motor was attached to the sprinting

186 athlete with a belt around the waist. The resistance/assistance load (Table 2) was  
187 determined and controlled by the Quantum computer application (1080 Motion,  
188 Lidingö, Sweden). Gear 1 and isotonic resistance mode were used for the winch  
189 system. For the resisted 30-m sprints, the players started 5 m in front of and ran away  
190 from the machine. The variable resistance mode was used the last three weeks (i.e., the  
191 tapering phase) for ITG<sub>1</sub> and in two training sessions in the middle of the intervention  
192 for ITG<sub>3</sub> to ensure a smooth transition from resisted to assisted sprinting. In this mode,  
193 the resistance drops linearly from 9 kg at start to 1 kg when achieving a certain speed  
194 (corresponding to each individual's documented peak velocity at running with 9 kg  
195 resistance, assessed by the 1080 device). For the assisted 25-m sprints, the subjects  
196 started 45 m in front and ran towards the machine. The assisted sprints were slightly  
197 shorter to ensure sufficient braking distance. During the assisted sprints, participants  
198 were advised to focus on high step frequency when they approached their maximal  
199 velocity, as previously recommended (Mero & Komi, 1986; Cissik, 2005). No other  
200 technical instructions were provided. Overall, sprinting with 5, 8 and 11 kg resistance  
201 induced 11, 18 and 25% reduction in maximal sprint velocity on average, based on  
202 assessments of the sprint training sessions. Similarly, sprinting with 0.3, 1.3, 2.2 and  
203 3.2 kg assistance induced 1, 6, 11 and 14% higher maximal velocity. All the stated  
204 resistance/assistance values are averaged over the entire step cycle. The variability for  
205 each assistance/resistance load was very low (CV < 1%, calculated from 201 runs),  
206 indicating high reliability.

207

## 208 *Statistics*

209 Shapiro Wilks tests revealed that none of the variables deviated statistically from  
210 distribution of normality. Data from pre- and post-training tests are presented as mean  
211  $\pm$ SD. Magnitudes of between-group differences were assessed by standardisation

212 (mean difference divided by the harmonic mean of the SD of the compared groups).  
213 The thresholds for assessing the observed difference in means were 0.2, 0.6 and 1.2  
214 for small, moderate and large, respectively (Hopkins, Marshall, Batterham, & Hanin,  
215 2009). To make inferences about true values of effects, we used non-clinical  
216 magnitude-based inference rather than null-hypothesis significance testing (Hopkins  
217 et al., 2009). Magnitudes were evaluated mechanistically: if the confidence interval  
218 overlapped substantial positive and negative values, the effect was deemed unclear;  
219 otherwise effects were deemed clear and shown with the probability that the true effect  
220 was substantial or trivial (whichever was greater) using the following scale: 25-75%,  
221 possibly; 75-95%, likely; 95-99.5%, very likely; > 99.5%, most likely (Hopkins et al.,  
222 2009).

223

## 224 **Results**

225 \*\*\*Table 3 about here\*\*\*

226

227 Sprint performance and mechanical outputs between and within groups from pre- to  
228 post-training test are shown in Table 3. Both groups improved their 30-m sprint  
229 performance by 0.05-0.06 s on average (~ 1%; small effect). Both groups improved  
230 V0 by ~ 2% (moderate effect), while only trivial or small effect magnitudes were  
231 observed for the other mechanical outputs. All between-group differences observed  
232 from pre- to post-training test were trivial and unclear.

233

234 \*\*\*Figure 2 about here\*\*\*

235

236 Figure 2 shows the changes in 30-m sprint time and V0 from pre- to post-training tests  
237 on an individual level. No clear trends between treatment conditions and performance  
238 enhancements were observed.

239

## 240 **Discussion**

241 To the authors' knowledge, this is the first study to evaluate the effect of an  
242 individualised sprint-training program based on horizontal force-velocity profiling.  
243 Our main finding was that the individualised training was no more effective than a  
244 generalised sprint training program (control) in elite female handball players. Hence,  
245 all between-group differences were trivial. Both the individualised training group and  
246 the control group displayed moderate improvements in maximal velocity (V0) and  
247 small enhancements in 0-30 m sprint times. Only trivial or small effect magnitudes  
248 were observed for variables related to horizontal force- and power production within  
249 both groups.

250 Individualised training is generally more challenging to organise (i.e., time  
251 consuming) for team-sport staff than common training sessions where "one size fits  
252 all." Consequently, many coaches perform similar training for most players on the  
253 team, despite considerable potential variances in capacity profiles. Interestingly, even  
254 though applying individualised training is theoretically and scientifically sound  
255 (Haugen et al., 2014; Morin & Samozino, 2016; Jiménez-Reyes et al., 2017<sup>A</sup>), the lack  
256 of substantial between-group differences observed in the present study do not support  
257 individualised sprint training. However, several considerations must be taken into  
258 account and discussed in order to avoid a potential type II error conclusion.

259 When optimally evaluating an intervention, it is important to consider (i) the actual  
260 change in performance (the signal), (ii) the noise associated with that particular  
261 assessment, and (iii) the smallest practical or meaningful change (SWC) (Hopkins,  
262 2004). SWC for team sport athletes is 1% for 10- to 40-m sprints and 2% for maximal  
263 velocity sprinting (Haugen & Buchheit, 2016). Considering that the actual change in  
264 performance (~ 1% for both groups over 30-m sprint) was practically identical with  
265 the measurement noise observed (1% CV for 0-30-m sprint time) and SWC for team  
266 sport athletes, the usefulness of the sprint training programs performed by both groups  
267 was relatively poor. However, we did observe large variations in individual responses  
268 (Figure 2). Ten out of 17 athletes (five from ITG and five from CG) improved their  
269 30-m times by more than 1% (SWC), indicating that the intervention was useful for  
270 these players, while three athletes (all from ITG) worsened their 30-m sprint times  
271 correspondingly by more than 1%. Similarly, nine players (five from ITG and 4 from  
272 CG) displayed advances in V0 greater than 2% (SWC), while one player decreased V0  
273 by more than 2%. The reasons for these variations remain unclear. No meaningful  
274 differences were observed between the groups in terms of sprint performance level,  
275 total training- or match-load characteristics during the intervention period. Moreover,  
276 a visual inspection of the present individual results revealed no clear trends in favour  
277 of any playing position.

278 Both groups displayed larger enhancements for maximal velocity sprinting than for  
279 accelerated sprint performance. Similar to our findings, Tønnessen, Shalfawi, Haugen,  
280 & Enoksen (2011) observed unaltered accelerated sprint performance and improved  
281 maximal velocity as a result of weekly repeated 40-m sprints in young male elite soccer  
282 players. A recent review by Rumpf et al. (2016) showed that training effects (in terms  
283 of effect size) increased with increasing sprint distance. Collectively, this suggests that

284 team sport players respond most strongly to somewhat longer and less team-sport  
285 specific sprint distances. Indeed, team sport players perform a high number of brief  
286 accelerations (~ 5-10 m) during training and games, while longer sprints (> 30 m)  
287 rarely occur (Vigne, Gaudino, Rogowski, Alloatti, & Hautier, 2010; Michalsik,  
288 Madsen, & Aagaard, 2014; Suarez-Arrones et al., 2014). Therefore, we speculate that  
289 most well-trained players have largely maximized their accelerated sprint performance  
290 potential (at least when compared to maximal velocity sprinting) during regular team-  
291 sport training.

292 Performance in sprint is determined by a complex interaction of technical and  
293 physiological variables (Morin, Edouard, & Samozino, 2011; Haugen et al., 2017<sup>A</sup>;  
294 Haugen, Paulsen, Seiler, & Sandbakk, 2017<sup>B</sup>). In the context of this study, it is  
295 important to keep in mind that ineffective sprinting (e.g., too much upper body raise  
296 during initial acceleration) may influence the mechanical outputs. That is, horizontal  
297 force- and power production may be underestimated for powerful athletes with poor  
298 running technique. Morin et al. (2011) have developed a model to calculate ratio of  
299 force and force application technique, but these computations require force data from  
300 instrumented treadmills or multiple force plates in series, equipment that the vast  
301 majority of athletes do not have access to.

302 The categorisation criteria that formed the basis for the present individualised sprint  
303 training need to be further discussed. Recently, Jimenez-Reyes et al. (2017) performed  
304 an intervention with a similar approach to enhance vertical jump performance, and  
305 their allocation to the different training protocols was based on percentage deviation  
306 from the theoretically optimal FV profile. As no such reference values exist for  
307 horizontal sprinting, a relative allocation model was chosen for the present study. Due  
308 to the strong relationship between FV slope and body mass (we observed a 0.80

309 correlation between these variables based on pre-training tests), it is crucial to  
310 normalise FV slope to body mass prior to group allocation, as performed in this study.  
311 However, it remains unclear whether the participants conducted an optimal training  
312 protocol based on the principle of targeting their least developed capacity (e.g. force-  
313 deficit or velocity-deficit). Morin & Samozino (2016) suggested that individual  
314 training programs should be based on comparisons of the relative strengths and  
315 weaknesses in each player's horizontal profile compared to the rest of the team.  
316 However, a limitation of using this approach is that it is directly affected by group  
317 homogeneity. Theoretically, the players included in this study might be clustered  
318 around a smaller part of the entire spectrum of mechanical sprint running profiles,  
319 leading to the possibility that the prescribed individualised training was too  
320 differentiated.

321 Due to the varying natures and specificities across team sports, the importance of  
322 sprint-specific mechanical outputs will vary. Giroux, Rabita, Chollet, & Guilhem  
323 (2016) observed that the chronic practice of an activity leads to differently balanced  
324 force-velocity profiles in squat jumping. Further research should therefore aim to  
325 establish the requirements of sprint-specific mechanical outputs across a broad range  
326 of sports disciplines and playing positions in order to provide a holistic picture of the  
327 capacity profile continuum. Differences in force-velocity profiles raise potential  
328 sources of performance improvement in elite athletes. As such, it is reasonable to  
329 assume that the effect of individualised training increases with athlete heterogeneity.

330 Despite some potential methodological weaknesses associated with the current  
331 individualisation of sprint training, no indications in favour of either resisted or  
332 assisted sprint training were observed (Figure 2). The hypothesis behind assisted sprint  
333 running is that supramaximal sprinting can lead to higher stride-frequency, shorter

334 ground contact times and higher angle velocities (Cissik, 2005). Comparisons of  
335 assisted sprint-training protocols across studies are even more challenging than for  
336 resisted sprinting, due to fewer scientific publications and even greater variations in  
337 methods and devices (e.g., downhill running, treadmill, elastic cord devices, etc.).  
338 Clark et al. (2009) suggested that a towing load corresponding to ~4% of body weight  
339 decreases ground contact times without any negative effects on other kinematic  
340 parameters. In the present study, pulling forces in the range 0.3-3.2 kg (i.e., 0.7-4.4%  
341 of mean body mass) were used, inducing 1-14% increase in maximal sprint velocity.  
342 Because no kinematic recordings of test-runs were performed, the possible influence  
343 of the overspeed load on sprint kinematics remains unclear.

344 The horizontal resistances applied in the current study were 5, 8 and 11 kg, leading to  
345 a reduction in maximal velocity in the range 11-25%. According to the classifications  
346 outlined by Petrakos et al. (2015), this reduction in running velocity corresponds to  
347 moderate to heavy resistance. According to Cross, Brughelli, Samozino, Brown, &  
348 Morin (2017), the optimal loading for maximising power during sled-resisted sprinting  
349 is a resistance that reduces the maximal velocity by  $\approx$ 50%. However, Morin et al.  
350 (2016) tested the use of very heavy sleds and observed a substantial, increased  
351 horizontal force production when compared to non-resisted sprinting. Still, only trivial  
352 between-group differences were observed for power output and sprint velocity. Future  
353 studies should therefore investigate the effect of heavier or lighter loads after  
354 individualisation of force-velocity profiles.

355 Intervention studies involving high-level athletes are typically shaped by training-  
356 related constraints within the overall training program. Such constraints are an  
357 important aspect of assessing the practical efficacy of training interventions in team  
358 sports. This intervention was performed in-season, and it is possible that the results



359 would have been different if the study was undertaken off-season or pre-season.  
360 However, the present results add further support to the notion that sprinting skills over  
361 short distances are hard to improve within the constraints of overall team sport training  
362 (Tønnessen et al., 2011 and 2015; Haugen et al., 2015, Los Arcos & Martins, 2018).  
363 If the primary goal for well-trained players is to improve their sprinting skills, future  
364 investigations should explore whether it is more effective to restructure the players`  
365 weekly team sport training rather than introducing an additional physical training  
366 regime.

367 Considering both the present findings and previous research (Haugen et al., 2014;  
368 Petrakos et al., 2016; Rumpf et al., 2016), no specific sprint training methods have so  
369 far emerged as superior. However, there are many parameters left that need to be  
370 explored within the individualised FV-profile approach (e.g., other volume/load,  
371 proportions of assisted/resisted sprinting relative to normal sprinting, categorisation  
372 criteria for FV-profiling of athletes, sprint training at other season times, etc.).  
373 Therefore, the current findings must be interpreted with caution.

374

## 375 **Conclusion**

376 In the present study, elite female handball players were followed over 8 weeks in  
377 season. An individualised sprint-training program, based on horizontal force-velocity  
378 profiling, was found to be no more effective than a generalised sprint-training program  
379 in improving accelerated and maximal velocity sprinting performance. The moderate  
380 sample sizes may mask possible significant outcomes within the groups, but based on  
381 the trivial or small effect magnitudes observed, it is not likely that larger sample sizes  
382 would provide significant between-group differences. However, several other  
383 considerations must be taken into account and addressed in future studies before the

384 hypothesis can be rejected, the most important being the development of sport-specific  
385 categorisation criteria based on FV-profiling of athletes. Although the present  
386 investigation must be considered a pilot, it provides a point of departure for future  
387 studies.

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516 **Table 1.** Weekly training characteristics for the participants during the intervention  
 517 period

	<b>Specific (<i>n</i>)</b>	<b>Non-specific (<i>n</i>)</b>	<b>Games per week (<i>n</i>)</b>	<b>Total training volume (<math>\text{h}\cdot\text{w}^{-1}</math>)</b>	<b>Session RPE</b>	<b>PRS</b>
ITG	3.1±0.5	1.0±0.2	1.3±0.3	9.3±0.7	5.6±0.7	6.2±0.5
CG	2.7±0.4	1.1±0.4	1.4±0.3	8.8±0.8	5.8±0.5	6.7±1.1

518 Values are mean ± SD. Specific = handball-specific training on court. Non-specific =  
 519 non-specific handball training off-court (e.g., upper-body work, core stability,  
 520 recovery training, etc.). Session RPE = session rated perceived exertion. PRS =  
 521 perceived recovery status. All between-group differences were small or moderate.  
 522

523 **Table 2.** Sprint training intervention protocol

Sprint session	<i>n</i>	Resistance (kg) during 30-m sprints for ITG <sub>1</sub>	Assistance (kg) during 25-m sprints for ITG <sub>2</sub>	Resistance (session 1-8) and assistance (session 9-16) for ITG <sub>3</sub> (kg)
1	6	5-5-8-11-8-5	0-0-0.3-1.3-0.3-0	5-5-8-11-8-5
2	6	0-5-8-11-8-5	0-0-0.3-1.3-0.3-0.3	0-5-8-11-8-5
3	7	0-5-5-8-11-8-5	0-0.3-0.3-1.3-0.3-1.3-0.3	0-5-5-8-11-8-5
4	8	5-5-8-8-11-11-8-5	0-0-0.3-0.3-1.3-2.2-1.3-0.3	5-5-8-8-11-11-8-5
5	10	5-5-8-8-8-11-11-8-8-5	0-0-0.3-0.3-1.3-1.3-2.2-3.2-2.2-0	5-5-8-8-8-11-11-8-8-5
6	8	0-5-8-8-11-11-8-5	0-0-0.3-1.3-2.2-1.3-0.3-0	0-5-8-8-11-11-8-5
7	11	5-5-8-8-8-11-11-8-8-8-5	0-0-0.3-0.3-1.3-1.3-2.2-2.2-3.2-2.2-0	0-5-8-8-8-8- <u>11-11-11-11-11</u>
8	8	0-5-8-8-11-11-8-5	0-0-0.3-1.3-2.2-1.3-0.3-0	0-5-8-8- <u>11-11-11-11</u>
9	12	5-5-8-8-8-11-11-11-8-8-8-5	0-0-0.3-0.3-1.3-1.3-2.2-2.2-3.2-2.2-1.3-0	0-0-0-0.3-0.3-1.3-1.3-2.2-1.3-0-0-0
10	8	0-5-8-8-11-11-8-5	0-0-0.3-1.3-2.2-1.3-0.3-0	0-0-0.3-1.3-2.2-1.3-0.3-0
11	12	0-5-8-8-8-11-11- <u>11-11-11-11-11</u>	0-0-0.3-0.3-1.3-1.3-2.2-2.2-3.2-2.2-1.3-0	0-0-0.3-0.3-1.3-1.3-2.2-3.2-2.2-1.3-0-0
12	8	0-0-5-8-11- <u>11-11-11</u>	0-0-0.3-1.3-2.2-1.3-0.3-0	0-0-0.3-1.3-2.2-1.3-0.3-0
13	10	0-0-5-8-8- <u>11-11-11-11-11</u>	0-0-0.3-1.3-2.2-3.2-3.2-2.2-1.3-0	0-0-0.3-1.3-2.2-3.2-3.2-2.2-1.3-0
14	8	0-0-5-5-8- <u>11-11-11</u>	0-0-0.3-1.3-2.2-3.2-2.2-0	0-0-0.3-1.3-2.2-3.2-2.2-0
15	8	0-0-0-5-8- <u>11-11-11</u>	0-0-0.3-1.3-2.2-3.2-2.2-0	0-0-0.3-1.3-2.2-3.2-2.2-0
16	6	0-0-0-0-5- <u>11</u>	0-0-0.3-1.3-0-0	0-0-0.3-1.3-0-0

524 *n* = sprint repetitions (for CG and ITG). Underlined numbers denote sprints with variable resistance (linearly falling from 11 to 3 kg at a  
525 running velocity that corresponds to an individual peak velocity with 11 kg resistance). All stated resistance/assistance values are averaged  
526 over the entire step cycle.

527 **Table 3.** Sprint performance and mechanical outputs within and between groups from pre- to post-training test.

Variable	Individualised training group (ITG)			Control group (CG)			Between-group difference <i>Mean, ±90%CL; effect</i>
	<i>Pre</i>	<i>Post</i>	$\Delta$	<i>Pre</i>	<i>Post</i>	$\Delta$	
0-30 m sprint (s)	4.38 ± 0.17	4.33 ± 0.09	-0.05 ± 0.11	4.40 ± 0.11	4.35 ± 0.11	-0.05 ± 0.05	-0.01, ±0.04; trivial
V0 (m·s <sup>-1</sup> )	8.1 ± 0.4	8.2 ± 0.3	0.10 ± 0.3	8.0 ± 0.3	8.2 ± 0.3	0.2 ± 0.1	0.0, ±0.1; trivial
P0 (W)	1076 ± 122	1100 ± 72	24 ± 70	1050 ± 92	1061 ± 117	11 ± 43	16, ±35; trivial
P0·kg <sup>-1</sup> (W·kg <sup>-1</sup> )	14.7 ± 1.5	15.0 ± 0.9	0.3 ± 0.9	14.6 ± 0.8	14.8 ± 0.9	0.2 ± 0.6	0.1, ±0.5; trivial
F0 (N)	534 ± 47	539 ± 43	5 ± 27	527 ± 41	522 ± 51	-4 ± 24	10, ±22; trivial
F0·kg <sup>-1</sup> (N·kg <sup>-1</sup> )	7.3 ± 0.5	7.4 ± 0.4	0.0 ± 0.4	7.3 ± 0.3	7.3 ± 0.3	0.0 ± 0.3	0.1, ±0.3; trivial
FV-profile (slope·kg <sup>-1</sup> )	0.90 ± 0.06	0.89 ± 0.07	-0.01 ± 0.05	0.91 ± 0.04	0.89 ± 0.04	-0.02 ± 0.05	0.01, ±0.04; trivial

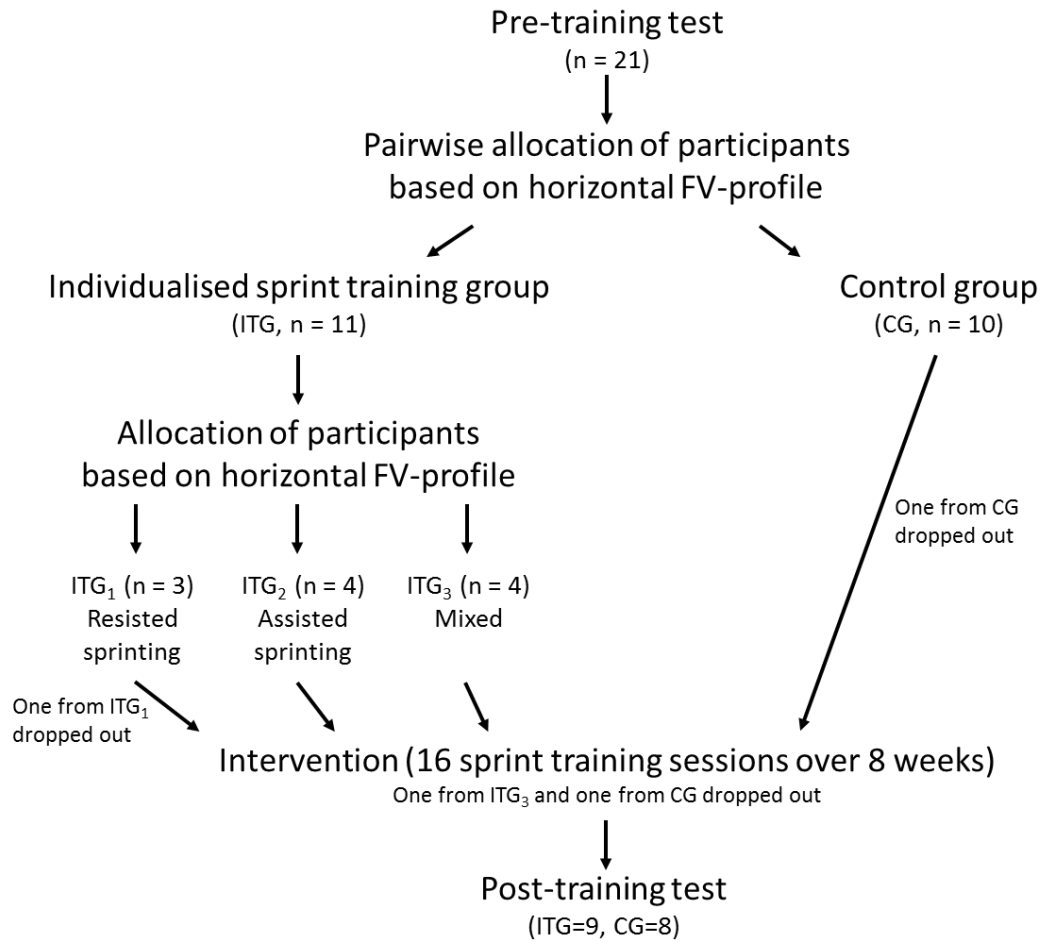
528 V0 = theoretical maximal velocity, P0 = maximal horizontal power, F0 = maximal horizontal force, FV-profile = force-velocity profile.

529 All inferences for between-group differences were unclear.

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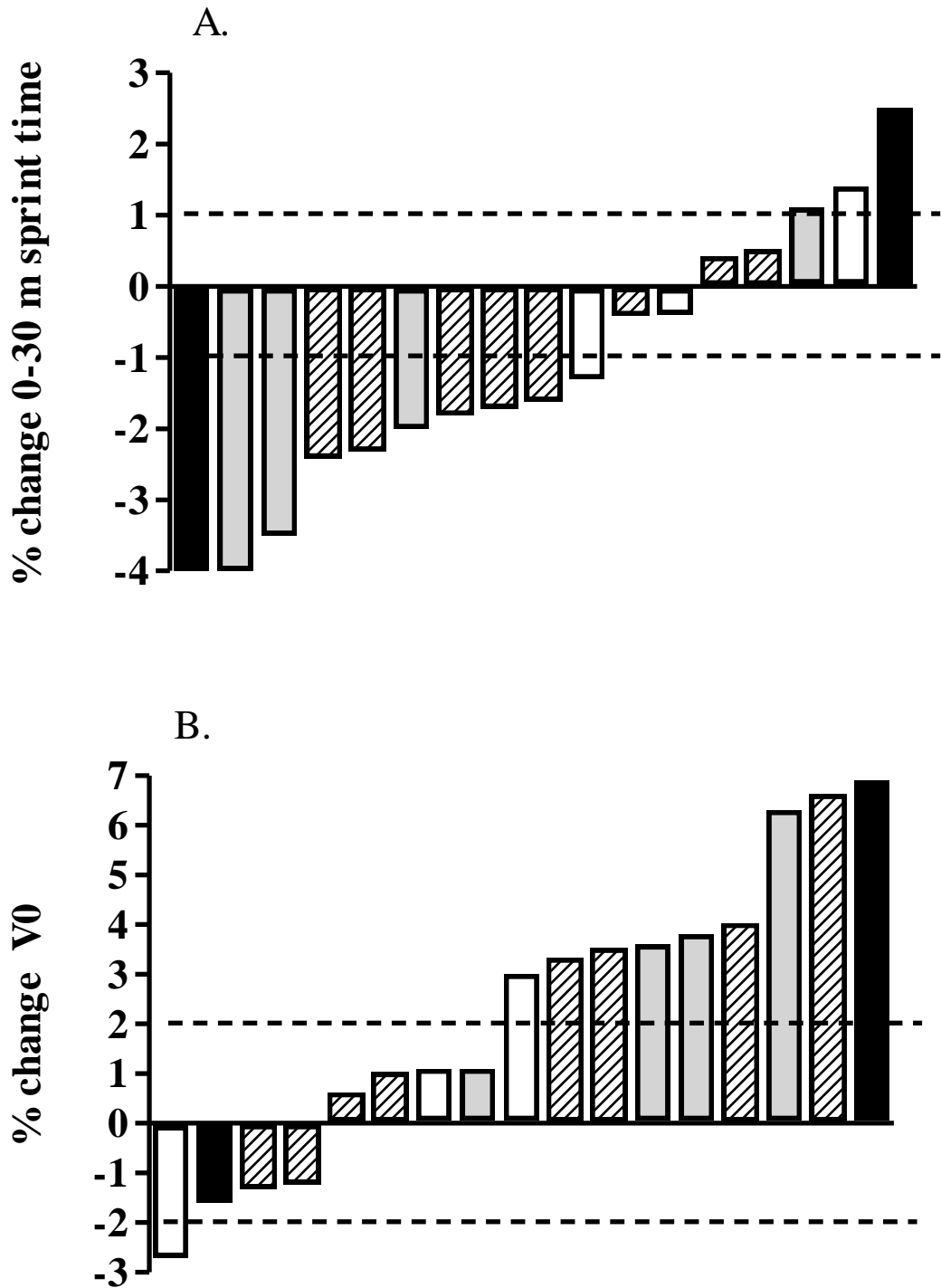
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532 **Figure 1.** Schematic overview of the study process  
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538 **Figure 2.** Individual relative changes in 30-m sprint time (Panel A) and theoretical  
 539 maximal velocity (V0) (Panel B) from pre- to post-training tests. Striped bars = CG,  
 540 black bars = ITG<sub>1</sub>, grey bars = ITG<sub>2</sub>, white bars = ITG<sub>3</sub>. Dotted lines denote smallest  
 541 worthwhile change.  
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