



THE UNIVERSITY *of* EDINBURGH

Edinburgh Research Explorer

Determinants for table tennis performance in Elite Scottish Youth players using a multidimensional approach

Citation for published version:

Doherty, S, Martinent, G, Martindale, A & Faber, I 2018, 'Determinants for table tennis performance in Elite Scottish Youth players using a multidimensional approach: A pilot study', *High Ability Studies*, pp. 1-15. <https://doi.org/10.1080/13598139.2018.1496069>

Digital Object Identifier (DOI):

[10.1080/13598139.2018.1496069](https://doi.org/10.1080/13598139.2018.1496069)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Peer reviewed version

Published In:

High Ability Studies

Publisher Rights Statement:

This is an Accepted Manuscript of an article published by Taylor & Francis in High Ability Studies on 18/07/18, available online: <https://www.tandfonline.com/doi/abs/10.1080/13598139.2018.1496069>

General rights

Copyright for the publications made accessible via the Edinburgh Research Explorer is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The University of Edinburgh has made every reasonable effort to ensure that Edinburgh Research Explorer content complies with UK legislation. If you believe that the public display of this file breaches copyright please contact openaccess@ed.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.



1 Running Head: MULTIDIMENSIONAL TALENT DEVELOPMENT

2 Determinants for Table Tennis Performance in Elite Scottish Youth Players Using a
3 Multidimensional Approach: A Pilot Study

4 Sean A. Picton Doherty¹, Guillaume Martinent², Amanda Martindale¹, Irene R. Faber^{3,4,5}

5 ¹Institute of Sport, Physical Education and Health Sciences, Moray House School of Education, The
6 University of Edinburgh, United Kingdom, ²Univ Lyon, University of Claude Bernard Lyon 1,
7 Laboratory of Vulnerabilities and Innovation in Sport (EA 7428), Interdisciplinary Confederation
8 Research in Sport (FED 4272), F-69622, Lyon, France, ³ Institute of Sport Science, University of
9 Oldenburg, Oldenburg, Germany. ⁴ Faculty of Physical Activity and Health, Saxion University of
10 Applied Sciences, Enschede, The Netherlands. ⁵International Table Tennis Federation, Lausanne,
11 Switzerland.

12 Corresponding author:

13 Guillaume Martinent, Ph.D., ²Univ Lyon, University of Claude Bernard Lyon 1, Laboratory of
14 Vulnerabilities and Innovation in Sport (EA 7428), Interdisciplinary Confederation Research in
15 Sport (FED 4272), 27-29 boulevard du 11 novembre 1918, F-69622, Lyon, France. E-mail:
16 guillaume.martinent@univ-lyon1.fr.

17 Date of initial submission: October 06, 2017.

18 Date of submission revised version: April 16, 2018.

19 Date of submission second revised version: May 23, 2018.

20 Word count (excl. abstract & references): 3982

21 Abstract word count: 196

22 Number of tables: 2

23 Number of supplementary material: 1

24 **Acknowledgements & Funding**

25 We acknowledge the children, parents and coaches for their cooperation in data-collection. Special
26 thanks go to the club members who provided the equipment and facilities and supported the
27 research. No financial support was provided for this study.

28 **Disclosure of interest**

29 The authors report no conflicts of interest.

30

31

32

33

34

35

36

37

38

39

40

41

42

43

44

45

46

47

48

49

50

51 **Abstract**

52 The purpose of the study is to explore whether a multidimensional profiling approach can be useful
53 in predicting a table tennis player's actual and future (one year later) performance. Data on
54 anthropometrics, age from peak height velocity, motor-skills, psychological skills and training
55 histories were gathered among Scottish elite youth male table tennis players (n=14). Significant
56 correlations emerged between: (a) actual performance rating and age from peak height velocity ($r =$
57 $.71$), sprint test ($r = -.69$), number of years of practice ($r = .84$), positive refocusing ($r = -.58$), and
58 self-regulation in learning – self-monitoring ($r = -.60$), and evaluation ($r = .57$); (b) performance
59 rating one year later and positive refocusing ($r = -.58$), self-monitoring ($r = -.50$) and number of
60 years of practice ($r = .80$). Results also showed significant correlations between progression scores
61 (2017 rating score minus 2016 rating score) and age from peak height velocity ($r = -0.77$), sprint
62 test ($r = .63$), number of years of practice ($r = -.52$), self-monitoring ($r = .69$), and evaluation ($r = -$
63 $.58$). These results provided preliminary evidence for the usefulness of a multidimensional profiling
64 approach for predicting performance and progression in youth table tennis players.

65

66 Keywords: aptitude; racquet sports; talent development; predictive value of test

67

68 **Determinants for Table Tennis Performance in Elite Scottish Youth Players Using a**
69 **Multidimensional Approach: A Pilot Study**

70 The concept of talent has a long history of dividing opinion. In 1865, Sir Francis Galton first
71 conducted research into the possibility that excellence in different fields shares commonalities
72 (Galton, 1865). He concluded that offspring inherit natural ability from their parents, which allows
73 them to display expert/elite performance in a certain field. In the years following Galton’s research,
74 scholars have debated the importance of nature and nurture for the attainment of expert
75 performance. Today, several researchers have moved on from this debate and instead focus their
76 attention on explaining the complex relationships between nature, nurture and talent (Vaeyens,
77 Lenoir, Williams, & Philippaerts, 2009). A current leading theory is that talent is a
78 multidimensional, multiplicative and dynamic process (Simonton, 2001). Crucially, Simonton
79 argues that the concept of talent has been over simplified and instead offers a complex model,
80 which acknowledges the multifaceted nature of talent. Today Simonton’s view is widely accepted
81 by scholars (Reilly, Williams, Nevill, & Franks, 2000; Faber, Bustin, Oosterveld, Elferink-Gemser,
82 & Nijhuis-Van Der Sanden, 2015a), yet there are still many sport associations that rely on overly
83 simplistic and unidimensional talent identification models (Abbott, Button, Pepping, & Collins,
84 2005).

85 In 1993, Ericsson, Krampe and Tesch-Römer published a seminar paper detailing their
86 theory of deliberate practice in which, they dismiss a correlation between natural ability and expert
87 performance. Deliberate practice is described by Ericsson et al. (1993) as relevant and effortful
88 practice, undertaken with the specific goal of improving performance. Ericsson et al. found that
89 differences in levels of expertise could be attributed to factors other than talent, most notably how
90 many hours of deliberate practice each individual had undertaken. Despite Ericsson et al.’s paper
91 gaining much support, providing the inspiration for the commonly known 10,000 hour rule
92 (Gladwell, 2008), their research also received much criticism. Ackerman (2013) claims that
93 scholars who support the deliberate practice approach such as Ericsson et al. (1993), fail to

94 acknowledge cases where different performers have undertaken extensive practice, but have not
95 displayed comparatively high levels of performance. Ericsson, Roring and Nandagopal (2007) state
96 that such incidents can be attributed to factors underpinning the development of players, such as
97 quality of coaching, access to facilities, and financial support. Ackerman (2013) acknowledges the
98 contribution of developmental factors. Nevertheless, he states that some differences in talent must
99 be due to natural ability. Thus, contrary to Ericsson et al. (1993), he states that giftedness does exist
100 and that it must contribute to the attainment of expert performance. Currently, the overall consensus
101 on expert performance in sport is that some element of both nature and nurture play a role in
102 determining success (Davids & Baker, 2007; Tucker & Collins, 2012). This study will employ a
103 multidimensional approach to talent identification and development in table tennis, which
104 acknowledges the potential importance of both nature and nurture.

105 Expert performance in the modern era of table tennis places a multitude of demands on an
106 individual. Table tennis is a complex motor task which forces a player to plan and coordinate their
107 movements in a very small time frame (Faber, Nijhuis-Van Der Sanden, Elferink-Gemser, &
108 Oosterveld, 2015b). Expert performance requires postural control, fast footwork, the ability to
109 anticipate, fast reaction time, and refined technical ability (Ak & Kocak, 2010; Akpinar, Devrilmez,
110 & Kirazci, 2012; Seve, Saury, Thereau, & Durand, 2002). An individual must be able to adjust their
111 movements to the infinite variations of speed, direction, height and spin that can be placed on the
112 ball (Limoochi, 2006; Rodrigues, Vickers, & Williams, 2002). Short and intense points mean
113 players predominantly use the anaerobic energy system. At an elite level, aerobic capacity is also
114 paramount to facilitate recovery between matches; international events usually last five to seven
115 days with matches on consecutive days (Kondric, Zagatto, & Sekulic, 2013). Moreover, in order to
116 undergo the volume and intensity of training necessary, expert performers must possess various
117 psychological qualities related to motivation, mental toughness, self-regulation, and emotional
118 regulation (Jonker, Elferink-Gemser, & Visscher, 2010; Chu, Chen, Chen, Huang, & Hung, 2012;
119 Lopez & Santelices, 2012). These psychological variables were selected, because they are likely to

120 help junior players to develop into elite players at senior level (Faber, 2016; Gucciardi, Hanton,
121 Gordon, Mallett, & Temby, 2015). Junior table tennis players are confronted with a series of
122 demands during their career and their competitive season such as a demanding training schedule or
123 intense competitive environment (Martinent, Decret, Guillet-Descas, & Isoard-Gauthier, 2014).
124 Therefore, maintaining a high level of motivation and engagement using emotional regulation
125 strategies to manage stressful events and being able to perform functionally in highly demanding
126 environments (mental toughness) are considered by several researchers and sport psychologists as
127 important qualities that junior players need to develop (Chu et al., 2011; Gucciardi et al., 2015;
128 Lonsdale, Hodge, & Rose, 2008; Martinent & Decret, 2015; Martinent, Ledos, Ferrand, Campo, &
129 Nicolas, 2015). Previous studies also provided evidence that self-regulation of learning (i.e., self-
130 directed processes that help individuals learn more effectively) is a crucial factor in talent
131 development (Jonker et al., 2010; Toering, Elferink-Gemser, Jonker, van Heuvelen, & Visscher,
132 2012). Due to the complex nature of both table tennis and talent, the task of identifying talent in
133 table tennis players is a significant challenge.

134 This study employs a multidimensional profiling model for table tennis proposed by Faber
135 et al. (2015a). At present, no other known study has researched critical determinants of performance
136 of elite table tennis players using a multidimensional model. Such a model would allow national
137 associations and coaches to assess a diverse range of variables, all of which are hypothesized to
138 contribute to (future) expert performance. At present, a wide range of national table tennis
139 associations do not use such a talent identification or development model. Rather, most of the
140 national table tennis associations select youth players for training groups and competitions based
141 mainly on the current performance level. As a minority sport in a relatively small nation, Table
142 Tennis Scotland has the challenge of maximizing the potential of their players with limited
143 resources. A multidimensional profiling model as proposed by Faber et al. (2015a) could facilitate
144 an improvement in talent development with reasonably low expense. It would allow coaches to

145 identify strengths and weaknesses in each individual and recognize how certain factors may be
146 limiting talent development (Abbott et al., 2005).

147 The purpose of the study is to explore whether a multidimensional profiling approach
148 (Faber et al., 2015a) including training history, anthropometric, the age from peak height velocity
149 (i.e. the time pre or post the onset of peak growth velocity which is a commonly used indicator of
150 maturity in adolescents, Mirwald, Baxter-Jones, Bailey & Beunen, 2002), motor-skill (eye-hand
151 coordination and sprint test) and psychological (motivation, engagement, mental toughness,
152 emotional regulation and self-regulation in learning) factors can be useful in predicting table tennis
153 player's performance. In particular, the research explored: (a) the relationships between
154 aforementioned variables grounded within the multidimensional profiling model and the actual and
155 future (one year later) performance of table tennis players; and (b) the relationships between
156 aforementioned variables from the multidimensional profiling model and the one-year progression
157 of table tennis players. Given the exploratory nature of the study, we did not test specific
158 hypotheses.

159 **Methods**

160 **Ethics statement**

161 This study and informed consent procedures were approved by the Moray House School of
162 Education (University of Edinburgh) ethics committee. A basic certificate was obtained from
163 Disclosure Scotland (an executive agency of the Scottish Government) to ensure eligibility to work
164 with children. Written informed consent was obtained for all participating players and their parents.

165 **Participants**

166 A purposive sample of 14 male Scottish junior table tennis players (M age = 15.3 years, SD = 1.2)
167 were recruited through written invitation. To be included in the study participants were required to
168 be male, eligible to compete in the junior (under 18) category, and ranked between one and twenty-
169 five in the junior national ranking list. The ranking system 'Ratings Central' (Ratings Central,

170 2016) was used to provide the player ranking list. It records all of a player's results in national
171 competitions, adding points for wins and subtracting points for losses, resulting in a rating.

172 **Design**

173 This study used an observational prospective design. Anthropometrics, motor-skills, psychological
174 skills, training history information and performance scores (performance rating) were gathered over
175 a period of two months. The performance rating was recorded again one year later.

176 **Data collection**

177 A test battery was used to measure anthropometry, maturity, motor and psychological skills and
178 training history. Each player individually first completed questionnaires concerning their training
179 history and the psychological skills. Consecutively, anthropological and motor-skill data were
180 gathered during a test session as part of their table tennis training. All participants were tested under
181 similar conditions in a training hall. The tester was familiarized with the test protocols and trained
182 by an expert table tennis trainer.

183 *Anthropometry and age from peak height velocity*

184 Anthropometric measures included weight, standing height and sitting height. The age from peak
185 height velocity (APHV) value for each individual was calculated using Mirwald et al.'s (2002)
186 equation using standing height, sitting height and chronological age. APHV is the most commonly
187 used indicator of maturity in longitudinal studies of adolescence (Mirwald et al., 2002). It provides
188 an accurate benchmark of the maximum growth during adolescence and provides a common
189 landmark to reflect the occurrence of other body dimension velocities within and between
190 individuals using the known differential timings of growth of height, sitting height and leg length.

191 *Motor-skills*

192 The eye-hand coordination test and the sprint test were selected from the Dutch motor skills
193 assessment and have demonstrated adequate validity and reliability (Faber, Oosterveld, & Nijhuis-
194 Van der Sanden, 2014). The eye-hand coordination test assesses the player's ability to make
195 accurate and coordinated hand and arm movements at a high rate. Players are required to throw a

196 table tennis ball against a table tennis table, which has been set up standing vertically upright. They
197 must throw and catch the ball with alternate hands from a distance of one meter as many times as
198 possible in 30 seconds. All players have two attempts and the highest score of correctly caught balls
199 is recorded.

200 The sprint test assesses a player's ability to accelerate and make direction changing turns
201 quickly in combination with a manual task (Faber et al., 2014). Five trays with a table tennis ball in
202 each are placed at specific positions in a pyramid shape circuit (Faber et al., 2014; 2015a). The
203 player is instructed to get the balls from each tray one by one to the starting position and also bring
204 them back as quickly as possible. Players have two attempts with sufficient rest in between and the
205 fastest time is recorded in seconds (for a full description see Faber, Elferink-Gemser, Faber,
206 Oosterveld, & Nijhuis-Van der Sanden, 2016).

207 *Psychological skills*

208 A battery of theoretically-relevant questionnaires was used to assess various psychological skills
209 involved in talent development (sport motivation, engagement, emotional regulation, mental
210 toughness, and self-regulation in learning). The Behavioral Regulations in Sport Questionnaire
211 (BRSQ; Lonsdale et al., 2008) was used to assess six distinct players' motives for table-tennis using
212 four-item subscales: intrinsic motivation, integrated regulation, identified regulation, introjected
213 regulation, external regulation, and amotivation. Participants responded to each of the items using a
214 Likert-type scale ranging from (1) not at all true, to (7) very true. Engagement was assessed with an
215 adaptation to the sporting context of the short form of the Utrecht Work Engagement Scale (UWES-
216 9; Schaufeli, Bakker, & Salanova, 2006). The UWES-9 is comprised of three three-item subscales
217 measuring vigor, dedication, and absorption through a Likert-type scale ranging from (0) never, to
218 (6) always. The short version of the Cognitive Emotion Regulation Questionnaire (short CERQ; 18
219 items; Garnefski & Kraaij, 2006) was used to measure adaptive (positive refocusing, positive
220 reappraisal, putting into perspective, refocusing on planning, acceptance) and maladaptive
221 emotional regulation strategies (rumination, self-blame, blaming other, catastrophizing) that

222 characterise the player's style of responding to stressful events through a Likert-type scale ranging
223 from (1) almost never, to (5) almost always. The Mental Toughness Index (MTI; 8 items; Gucciardi
224 et al., 2015) was used to assess mental toughness from a unidimensional perspective through a
225 Likert-type scale ranging from (1) false, 100% of the time, to (7) true, 100% of the time. Finally,
226 the Self-Regulation of Learning Self-Report Scale (SRL-SRS; Toering et al., 2012) was used to
227 assess the six dimensions of the self-regulation of learning concept: reflection (5 items), evaluation
228 (8 items), planning (8 items), self-monitoring (6 items), effort (9 items), and self-efficacy (10
229 items). The reflection and evaluation items were completed using a Likert-type scale ranging from
230 (1) strongly disagree/never, to (5) strongly agree/always whereas the planning, self-monitoring,
231 effort and self-efficacy items were answered using a 4 Likert-type scale ranging from (1) almost
232 never to (5) almost always (Toering et al., 2012). Previous research lent credit to the validity and
233 reliability of BRSQ, UWES-9, short CERQ, MTI, and SRL-SRS scores (Garnefski & Kraaij, 2006;
234 Gucciardi et al., 2015; Lonsdale et al., 2008; Schaufeli et al., 2006; Toering et al., 2012).

235 *Training history*

236 Data for training history was gathered using a questionnaire requesting participants to outline how
237 many years and the total training volume (hours) they had been actively practicing table tennis with
238 a coach.

239 **Statistical Analysis**

240 IBM SPSS Statistics 22 for Windows (IBM Corp., Armonk, NY, USA) was used for the statistical
241 analyses. Due to the violation of normality for some variables, the Spearman's rank-order
242 correlation was used to examine the relationships between the player's performance ratings (at the
243 time of first data gathering and one year later) and the motor-skill (e.g., sprint test, eye-hand test)
244 and psychological (e.g. engagement, emotional regulation strategies) abilities as well as training
245 history and anthropometric variables. Effect sizes can be defined as small ($0.3 < r < 0.5$), moderate
246 ($0.5 < r < 0.7$), or large ($0.7 < r$) (Hinkle, Wiersma, & Jurs, 2003).

247

Results

248 Table 1 presents the descriptive of all the study variables: anthropometry, age from peak height
249 velocity, motor skills, psychological skills, training history and table tennis performance. Only one
250 outlying data point was identified; one player scored more than -3 standard deviations away from
251 the mean of the variable integrated regulation.

252 ****INSERT TABLE 1 NEAR HERE****

253 Results of Spearman's rank-order correlations are presented in Table 2. Results showed
254 significant ($P < .05$) correlations between actual performance rating and APHV ($r = .71$), sprint test
255 ($r = -.69$), number of years of practice ($r = .84$), emotional regulation (i.e., positive refocusing; $r = -$
256 $.58$), and two dimensions of self-regulation in learning – self-monitoring ($r = -.60$), and evaluation
257 ($r = .57$). Otherwise, performance rating one year later was significantly correlated with positive
258 refocusing ($r = -.58$) and number of years of practice ($r = .80$) and marginally ($P \leq .09$) correlated
259 with self-monitoring ($r = -.50$). Finally, results showed significant correlations between progression
260 scores (2017 rating minus 2016 rating) and APHV ($r = -0.77$), sprint test ($r = .63$), self-monitoring
261 ($r = .69$), and evaluation ($r = -.58$), whereas progression scores were marginally correlated with
262 number of years of practice ($r = -.52$).

263 Moreover, a detailed correlation matrix of all included variables is added as supplemental
264 online material. Albeit non-significant (probably because of the small sample size), some
265 correlations were higher than .30 or lower than -.30: (a) the correlations between actual
266 performance rating and mental toughness ($r = .32$), integrated regulation ($r = -.32$), identified
267 regulation ($r = -.38$), introjected regulation ($r = -.34$), refocus on planning ($r = .47$), planning ($r =$
268 $.52$), and effort ($r = .43$); (b) the correlations between performance rating one year later and APHV
269 ($r = .45$), sprint test ($r = -.44$), introjected regulation ($r = -.33$), acceptance ($r = -.32$), refocusing on
270 planning ($r = .49$), blaming others ($r = -.35$), evaluation ($r = .34$), planning ($r = .52$), and effort ($r =$
271 $.50$); and (c) the correlations between progression scores and dedication ($r = .37$), intrinsic
272 motivation ($r = .43$), integrated regulation ($r = .37$), identified regulation ($r = .33$), amotivation, ($r =$
273 $-.43$), planning ($r = -.32$) and training history ($r = -.52$).

274 ****INSERT TABLE 2 NEAR HERE****

275 **Discussion**

276 A group of Scottish elite junior table tennis players were profiled using a multidimensional model
277 to test for distinguishing factors of performance and development. The primary determinants of
278 development in this sample were APHV, sprint time, self-regulation and number of years of
279 practice. These results provide preliminary evidence for a multidimensional profiling approach as
280 training history, anthropometrics, motor and psychological skills were significantly related to both
281 performance and progression scores. The players were likely to improve their performance more
282 over the course of the year if they were less physically mature, had a slower sprint time, and had
283 practiced less at the initial time of testing. It is theorised that the greater performance increase was
284 primarily due to the physical maturation those players would have experienced during the one year
285 period. The strongest correlation was observed between performance scores and training history.
286 The players who had practiced for longer and for more hours were likely to be at a higher
287 performance level at both time points. This is thought to be due to the extra practice time amassed
288 by the higher ranked players, allowing them to develop and refine their sport specific abilities to a
289 higher level. Consequently, mapping these performance determining characteristics might be
290 beneficial for talent development purposes.

291 The significant correlations between both APHV and sprint time with the progression
292 scores reveals the important role that physical maturation, for which APHV can be used as proxy,
293 can play in the performance development of young table tennis players. The results show that the
294 slower and less physically mature (i.e., lowest APHV) players were able to progress more during
295 the year than their faster and more physically mature counterparts, suggesting that they were able to
296 do so due to their own natural physical development. These results suggest that physical attributes
297 may be one of the primary determinants of performance development in elite youth table tennis
298 players. These results are in line with other studies on physical maturation that have shown that
299 even a difference of a few months in age may have a significant effect on athletic development

300 (Cobley, Baker, Wattie, & McKenna, 2009). Furthermore, it aligns to a previous study that shows
301 the predictive value of the sprint test for performance in youth table tennis players (Faber et al.,
302 2016).

303 The significant correlations found for psychological skills suggest that self-monitoring and
304 evaluation (two dimensions of self-regulation) had an influence on performance and progression.
305 However, the results were somewhat contradictory since evaluation was positively and self-
306 monitoring negatively correlated with performance rating (Toering et al., 2009). The significant
307 negative correlations of positive refocusing for both performance ratings suggest this may be a skill
308 that is required by lower rated players, perhaps since they are likely to experience more defeats than
309 the higher rated players. Although several psychological skills (e.g., sport motivation, engagement,
310 mental toughness) were non-significantly related to performance and progression scores, it is
311 noteworthy that some correlations showed a size of at least .30 (or -.30). Confirming the postulates
312 of the self-determination theory, progression scores were (non-significantly) positively correlated
313 with self-determined forms of motivation (i.e., intrinsic motivation, integrated and identified
314 regulations) and negatively correlated with amotivation (Martinent et al., 2015). Evaluation,
315 planning and/or effort (i.e., three dimensions from the self-regulation concept) were (non-
316 significantly) positively correlated with actual performance rating, performance rating one year
317 later and progression scores. Otherwise, mental toughness was (non-significantly) positively
318 correlated with actual performance rating whereas dedication (one dimension from the engagement
319 concept) was (non-significantly) positively correlated with progression score. As a whole, it is
320 theorised that psychological skills were not strong determinants of performance or development in
321 this study due to the nature of the sample. Psychological skills might mainly be determinants of
322 performance amongst a group of elite players who have similar physical and technical
323 competencies. Due to the variation in age and training history of the participants, physical maturity
324 and sport specific technical ability were more influential. It is also possible that the timing of data
325 collection (i.e. one year between data gathering of psychological variables and the performance

326 ratings) could explain the weak number of significant variables observed between psychological
327 variables and performance/progression scores. Hence, if psychological variables could not
328 necessarily provide a direct advantage or disadvantage in short term performance development
329 (e.g., one year later), psychological variables could be more strongly related to future performance
330 levels of these players in the long term (e.g., five years later) (Martinet, Cece, Elferink-Gemser,
331 Faber, & Decret, in press).

332 The results of the analysis of number of years of practice highlight the influence of training
333 history on performance and development. These results are consistent with previous research
334 conducted on other sports (Davids & Baker, 2007; Phillips, Davids, Renshaw, & Portus, 2010). It is
335 suggested that the extra practice time amassed by the higher rated players has allowed them to
336 develop and refine their sport specific abilities to a higher level than the lower rated elite players
337 (Ericsson et al., 1993). The central nervous systems of the higher rated players have received a
338 higher level of conditioning through practice, allowing their muscles to perform within the unique
339 demands of table tennis more effectively than the lower rated players (Knudsen, 2004).

340 This research study would have benefited from another round of profiling using the
341 multidimensional model alongside the recording of the performance ratings one year following the
342 initial profiling. This would have given a clearer insight into which variables may have had an
343 influence on the progression scores and performance ratings one year later. Future research of a
344 multidimensional profiling model should aim to develop methods to acquire relevant information
345 regarding each individual's history of sport and activity, as studies have shown that ability is
346 transferrable between different sports (Davids & Baker, 2007). Although table tennis is generally
347 regarded as a sport requiring early start for expert performance (Faber et al., 2015a), experience in
348 similar activities at a young age may mean talent development is not hindered by an absence of
349 early specialisation. Future research should also aim to include considerations for other
350 developmental factors, which are known to be important for the development of young athletes,
351 such as parental support and access to quality coaching (Côte, 1999). This data could allow coaches

352 and sports scientists to develop a more detailed profile of every individual. To build upon the
353 research of this study, a similar study on elite senior table tennis players in Scotland would also be
354 beneficial. Profiling adults would reduce the potential effect of physical maturity and hours of
355 practice on assessment results, allowing more emphasis to be placed on the assessments of motor-
356 skills and psychological factors. Also, as Scotland is a relatively small table tennis nation with a
357 low level of participation, these findings may not be strictly relevant to larger table tennis nations
358 that have thousands of players at each age category. In addition, it's possible that the lack of
359 significant correlations between certain factors is due to the size of the studies' sample. As such, the
360 findings of this study should be applied to other nations and groups of players with careful
361 consideration.

362 In conclusion, assessing maturity, motor skills (sprint), psychological skills (self-regulation
363 in learning) and table tennis experience are likely to support talent development programs for elite
364 youth table tennis players, since these determinants showed significant associations with table
365 tennis performance and progression. These findings support the view that the focus of talent models
366 should be directed towards development, rather than selection (Wolstencroft, 2002). Longitudinal
367 studies that use a multi-dimensional profiling model of this nature are required to assess critical
368 determinants of performance over a longer period of time. A global research study utilizing a
369 comprehensive multi-dimensional profiling model could help facilitate a greater understanding of
370 the variables, which impact the attainment of expert performance in table tennis.

371 **References**

- 372 Abbott, A., Button, C., Pepping, G. J., & Collins, D. (2005). Unnatural selection: Talent
373 identification and development in sport. *Nonlinear Dynamics, Psychology, and Life*
374 *Sciences, 9*(1), 61-88.
- 375 Ackerman, P. L. (2013). Nonsense, common sense, and science of expert performance: Talent and
376 individual differences. *Intelligence, 45*, 6-17.

- 377 Ak, E., & Koçak, S. (2010). Coincidence-anticipation timing and reaction time in youth tennis and
378 table tennis players. *Perceptual & Motor Skills*, 110(3), 879-887.
- 379 Akpınar, S., Devrılmaz, E., & Kirazci, S. (2012). Coincidence-anticipation timing requirements are
380 different in racket sports. *Perceptual & Motor Skills*, 115(2), 581-593.
- 381 Chu, C. Y., Chen, I. T., Chen, L. C., Huang, C. J., & Hung, T. M. (2012). Sources of psychological
382 states related to peak performance in elite table tennis players. *International Journal of*
383 *Table Tennis Sciences*, 7, 86–90.
- 384 Cogley, S., Baker, J., Wattie, N., & McKenna, J. (2009). Annual age-grouping and athlete
385 development. *Sports Medicine*, 39(3), 235-256.
- 386 Côté, J. (1999). The influence of the family in the development of talent in sport. *The Sport*
387 *Psychologist*, 13(4), 395-417.
- 388 Davids, K., & Baker, J. (2007). Genes, environment and sport performance. *Sports Medicine*,
389 37(11), 961-980.
- 390 Elferink-Gemser, M. T., Jordet, G., Coelho-E-Silva, M. J., & Visscher, C. (2011). The marvels of
391 elite sports: how to get there? *British Journal of Sports Medicine*, 45(9), 683-684.
- 392 Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the
393 acquisition of expert performance. *Psychological Review*, 100(3), 363.
- 394 Ericsson, K. A., Roring, R. W., & Nandagopal, K. (2007). Giftedness and evidence for reproducibly
395 superior performance: An account based on the expert performance framework. *High Ability*
396 *Studies*, 18(1), 3-56.
- 397 Faber, I. R., Bustin, P. M., Oosterveld, F. G., Elferink-Gemser, M. T., & Nijhuis-Van der Sanden,
398 M. W. (2015). Assessing personal talent determinants in young racquet sport players: a
399 systematic review. *Journal of Sports Sciences*, 34(5), 395-410.
- 400 Faber, I. R., Elferink-Gemser, M. T., Faber, N. R., Oosterveld, F. G., & Nijhuis-Van der Sanden,
401 M. W. (2016). Can perceptuo-motor skills assessment outcomes in young table tennis

402 players (7–11 years) predict future competition participation and performance? An
403 observational prospective study. *PloS one*, *11*(2), e0149037.

404 Faber, I. R., Nijhuis-Van Der Sanden, M. W., Elferink-Gemser, M. T., & Oosterveld, F. G. (2015).
405 The Dutch motor skills assessment as tool for talent development in table tennis: a
406 reproducibility and validity study. *Journal of Sports Sciences*, *33*(11), 1149-1158.

407 Faber, I. R., Oosterveld, F. G., & Nijhuis-Van der Sanden, M. W. (2014). Does an eye-hand
408 coordination test have added value as part of talent identification in table tennis? A validity
409 and reproducibility study. *PloS one*, *9*(1), e85657.

410 Galton, F. (1865). Hereditary talent and character. *Macmillan's Magazine*, *12*, 157–166, 318–327.

411 Garnefski, N., Kraaij, V., & Spinhoven, P. (2001). Negative life events, cognitive emotion
412 regulation and emotional problems. *Personality and Individual Differences*, *30*(8), 1311-
413 1327.

414 Gucciardi, D. F., Hanton, S., Gordon, S., Mallett, C. J., & Temby, P. (2015). The concept of mental
415 toughness: tests of dimensionality, nomological network, and traitness. *Journal of*
416 *Personality*, *83*(1), 26-44.

417 Hinkle, D. E., Wiersma, W., & Jurs, S. G. (2003). *Applied statistics for the behavioral sciences*.
418 Boston, Mass: Houghton Mifflin

419 Jonker, L., Elferink-Gemser, M. T., & Visscher, C. (2010). Differences in self-regulatory skills
420 among talented athletes: The significance of competitive level and type of sport. *Journal of*
421 *Sports Sciences*, *28*(8), 901-908.

422 Knudsen, E. I. (2004). Sensitive periods in the development of the brain and behavior. *Journal of*
423 *Cognitive Neuroscience*, *16*(8), 1412-1425.

424 Kondrič, M., Zagatto, A. M., & Sekulić, D. (2013). The physiological demands of table tennis: A
425 review. *Journal of Sports Science and Medicine*, *12*, 362–370.

426 Larsen, R. J., & Diener, E. (1987). Affect intensity as an individual difference characteristic: A
427 review. *Journal of Research in Personality*, *21*(1), 1-39.

428 Lonsdale, C., Hodge, K., & Rose, E. A. (2008). The Behavioral Regulation in Sport Questionnaire
429 (BRSQ): Instrument development and initial validity evidence. *Journal of Sport & Exercise*
430 *Psychology, 30*(3), 323.

431 Lopez, A., & Santelices, O. (2012). Personality characteristics of elite table tennis athletes of the
432 Philippines: basis for a proposed recruitment program. *International Journal of Table Tennis*
433 *Sciences, 7*, 1-4.

434 Limoochi, S. (2006). A survey of table tennis coaches' opinions of some criteria in talent
435 identification. *International Journal of Table Tennis Sciences, 6*, 280–287.

436 Martinent, G., Cece, V., Elferink-Gemser, M., Faber, I., & Decret, J.-C. (in press). The prognostic
437 relevance of psychological factors with regard to participation and success in table-tennis.
438 *Journal of Sports Sciences*.

439 Martinent, G., & Decret, J.-C. (2015). Motivational profiles among young table-tennis players in
440 intensive training settings: A latent profile transition analysis. *Journal of Applied Sport*
441 *Psychology, 27*, 268-287.

442 Martinent, G., Decret, J. C., Guillet-Descas, E., & Isoard-Gauthier, S. (2014). A reciprocal effects
443 model of the temporal ordering of motivation and burnout among youth table tennis players
444 in intensive training settings. *Journal of Sports Sciences, 32*(17), 1648-1658.

445 Martinent, G., Ledos, S., Ferrand, C., Campo, M., & Nicolas, M. (2015). Athletes' regulation of
446 emotions experienced during competition: A naturalistic video-assisted study. *Sport,*
447 *Exercise, and Performance Psychology, 4*, 188-205.

448 Mirwald, R., G. Baxter-Jones, A., Bailey, D., & Beunen, G. (2002). An assessment of maturity
449 from anthropometric measurements. *Medicine & Science in Sports & Exercise, 34*(4), 689-
450 694.

451 Phillips, E., Davids, K., Renshaw, I., & Portus, M. (2010). Expert performance in sport and the
452 dynamics of talent development. *Sports Medicine, 40*(4), 271-283.

- 453 Ratings Central. (2016). *Ratingscentral.com*. Retrieved 1 December 2015, from
454 <http://www.ratingscentral.com/PlayerList.php>
- 455 Reilly, T., Williams, A. M., Nevill, A., & Franks, A. (2000). A multidisciplinary approach to talent
456 identification in soccer. *Journal of Sports Sciences, 18*(9), 695-702.
- 457 Rodrigues, S. T., Vickers, J. N., & Williams, A. M. (2002). Head, eye and arm coordination in table
458 tennis. *Journal of Sports Sciences, 20*, 187–200.
- 459 Schaufeli, W. B., Bakker, A. B., & Salanova, M. (2006). The measurement of work engagement
460 with a short questionnaire a cross-national study. *Educational and Psychological
461 Measurement, 66*(4), 701-716.
- 462 Sève, C., Saury, J., Theureau, J., & Durand, M. (2002). Activity organization and knowledge
463 construction during competitive interaction in table tennis. *Cognitive Systems Research,
464 3*(3), 501-522.
- 465 Simonton, D. K. (2001). Talent development as a multidimensional, multiplicative, and dynamic
466 process. *Current Directions in Psychological Science, 10*(2), 39-43.
- 467 Toering, T., Elferink-Gemser, M. T., Jonker, L., van Heuvelen, M. J., & Visscher, C. (2012).
468 Measuring self-regulation in a learning context: Reliability and validity of the Self-
469 Regulation of Learning Self-Report Scale (SRL-SRS). *International Journal of Sport and
470 Exercise Psychology, 10*(1), 24-38.
- 471 Tucker, R., & Collins, M. (2012). What makes champions? A review of the relative contribution of
472 genes and training to sporting success. *British Journal of Sports Medicine, 46*(8), 555-561.
- 473 Toering, T. T., Elferink-Gemser, M. T., Jordet, G., & Visscher, C. (2009). Self-regulation and
474 performance level of elite and non-elite youth soccer players. *Journal of Sports Sciences,
475 27*(14), 1509-1517.
- 476 Vaeyens, R., Güllich, A., Warr, C. R., & Philippaerts, R. (2009). Talent identification and
477 promotion programmes of Olympic athletes. *Journal of Sports Sciences, 27*(13), 1367-1380.

- 478 Vaeyens, R., Lenoir, M., Williams, A. M., & Philippaerts, R. M. (2008). Talent identification and
479 development programmes in sport. *Sports Medicine*, 38(9), 703-714.
- 480 Williams, A. & Reilly, T. (2000). Talent identification and development in soccer. *Journal of*
481 *Sports Sciences*, 18(9), 657-667.
- 482 Wolstencroft, E. (Ed.). (2002). *Talent identification and development: An academic review*. A
483 report for Sportscotland by The University of Edinburgh. Edinburgh: Sportscotland.

484 Table 1. Descriptive Statistics

		<i>M</i>	<i>SD</i>	Min.	Max.
Age (years)		13.7	3.5	12	17
Anthropometry	Weight (kg)	53	16	40	70
	Standing height (cm)	160	41	150	180
	Sitting height (cm)	78	20	70	92
Age from peak height velocity (years)		0.13	1.55	-2.38	2.62
Motor skills	Eye hand coordination (correctly caught balls)	31	8	27	39
	Sprint (s)	27	7	34	24
Psychological skills					
<i>Engagement</i>	Vigor	4.3	1.0	2.3	6
	Dedication	4.8	0.9	2.7	6
	Absorption	4.3	0.6	3.3	5.3
<i>Mental toughness</i>		5.7	0.3	5	6.4
<i>Sport motivation</i>	Intrinsic Motivation	4.7	0.5	3.5	5
	Integrated Regulation	3.9	0.9	1	5
	Identified Regulation	4.1	0.6	2.5	4.8
	Introjected Regulation	2.9	1.3	1	5
	External Regulation	2.0	0.8	1	3.5
	Amotivation	1.7	1.2	1	5
<i>Emotional regulation</i>	Self-blame	3.6	0.9	2	5
	Acceptance	3.7	0.9	2	5
	Rumination	3.4	0.9	2	5
	Positive Refocusing	2.5	1.2	1	4.5
	Refocus on Planning	3.8	0.7	2.5	5
	Positive Reappraisal	3.7	0.8	2.5	5
	Putting into Perspective	3.4	0.9	1.5	5
	Catastrophizing	2.7	1.1	1	5
	Blaming Others	1.8	0.6	1	3
<i>Self-regulation in</i>	Reflection	4.1	0.4	3.4	4.8

<i>learning</i>	Evaluation	3.7	0.6	2.6	4.4
	Planning	2.8	0.6	2.3	3.5
	Self-monitoring	2.8	0.5	1.7	3.5
	Effort	3.2	0.3	2.8	3.7
	Self-efficacy	3.0	0.4	2.4	3.8
<hr/>					
Training volume (hours)		2177	1518	864	5696
Training history (years)		5	2.2	3	10
Rating 2016 (points)		1354	290	815	1982
Rating 2017 (points)		1421	241	1009	1891
Progression 2016-2017 (points)		66	87	-91	194
<hr/>					

485 *Notes. M = mean, SD = standard deviation, min. = minimum, max = maximum.*

486 Table 2. Significant Spearman Rank-Order Correlations between Multidimensional Assessment
 487 Outcomes and Performance Indicators.

		Rating	Rating	Progression
		2016	2017	2016-2017
Maturity	APHV (years)	0.71*	0.45	-0.77*
Motor skills	Sprint (<i>seconds</i>)	-0.69*	-0.44	0.63*
Psychological skills	Positive	-0.58*	-0.58*	0.12
	Refocusing			
	Evaluation	0.57*	0.34	-0.58*
	Self-monitoring	-0.60*	-0.50 [‡]	0.69*
Training history	Number of years	0.84*	0.80*	-0.52 [‡]

488 Notes. APHV = age from peak height velocity; [‡] $P \leq 0.09$, * $P < 0.05$.