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► **To cite this version:**

Louise Robin, Laure Fernandez, Maxime Robert, Eric Hermand, Axelle Gelineau, et al.. Influence of daily physical activity on fine motor skills of adults around a Fitts task. *Folia Medica*, 2023, 65 (6), pp.950-957. 10.3897/folmed.65.e103060 . hal-04431499

HAL Id: hal-04431499

<https://hal.science/hal-04431499>

Submitted on 1 Feb 2024

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1 **Influence of Daily Physical Activity on Fine Motor Skills of Adults around a Fitts Task**

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13

14 **Abstract**

15 **Introduction:** Achieving our daily tasks depends on the speed-accuracy conflict. Physical
16 activity plays a role in the development of our motor skills. However, the relationship
17 between physical activity level (PAL) and fine motor skills remains largely unexplored.

18 **Aim:** Our aim was to examine the relationship between the amount of daily physical activity
19 and the performance of healthy adults in a reciprocal aiming task.

20 **Materials and methods:** Eighty-seven healthy adults completed a reciprocal aiming task
21 using a digital tablet. Four difficulty levels (3-6, determined by target width) and 50 scores
22 for each level were performed using both hands. Movement time, error rate, and performance
23 index were analyzed. PAL was measured using the Global Physical Activity Questionnaire.
24 Spearman correlations and nparLD analysis were used in R Studio to explore the influence of
25 physical activity level, difficulty index on individuals' performances.

26 **Results:** Apart from a correlation between PAL and motor performance at the easiest level
27 ($r=0.23$, $p=0.002$), there was no correlation between PAL and fine motor performance.

28 **Conclusions:** The results of our study did not indicate any significant major correlations
29 between daily PAL and fine motor performance except when the constraints of a reciprocal
30 aiming task are the lowest. Further work is needed to consider the use of the reciprocal Fitts
31 task in a clinical setting.

32

33 **Keywords**

34 adult, daily living, exercise, Fitts' law, motor skills, upper extremity

35

36

37 INTRODUCTION

38 The level of physical activity (PAL) varies from individual to individual and from lifestyle to
39 lifestyle these days. It is recognized as a good indicator of individuals' participation in their
40 daily activities.[1] The term "physical activity" (PA) is used as a generic term that includes
41 leisure, travel, domestic and occupational activities.[2] The compendium of PA has been
42 widely accepted as a resource for estimating and classifying the energy cost of human activity
43 in meta- bolic equivalent tasks (METs). One MET is considered to be the resting metabolic
44 rate or energy cost of a person at rest. MET values from the compendium range from 0.9
45 METs for sleep to 23 METs for a 14.0 mph run.[3] Stodden et al. suggest that the
46 development of motor skills has an impact on the PAL of young adults.[4] This relationship
47 between motor skills and PAL emerges in childhood and continues to strengthen during
48 adulthood.[5] At the same time, regu- lar PA improves individuals' motor performance.[6]
49 Motor performance is defined as a temporary state of motor behavior.[7] Its measurement is
50 specific to the task type and differs according to task difficulty, environment, and the
51 physiological characteristics of the individuals. It makes it possible to account for the motor
52 skills of indi- viduals.[8] Clinicians can assess motor performance when performing gross
53 motor tasks or fine manual activities us- ing several tests, specific to the examined functions
54 (e.g., the 6-minute walk test and the "Purdue Pegboard" dex- terity test).[9,10] However, due
55 to the variability and com- plexity of fine motor tasks, it is difficult to define standard
56 activities for the arm. Nevertheless, among the daily life tasks, "reaching" has the highest
57 priority: it is considered as the most important movement performed by the upper limb.[11]
58 Grasping a glass, for example, requires a reaching movement. The success and completion of
59 reaching tasks require movement adjustments to deal with the prevailing accuracy.
60 The trade-off between movement speed and accuracy is described in Fitts' law, which states
61 that movement time relates linearly to the index of difficulty (ID), which quan- tifies task
62 difficulty, in aiming tasks.[12,13] Relying on Shan- non and Weaver's (1949) information
63 theory, according to which a signal is transmitted through a processing channel that is
64 disturbed by noise[14], Fitts (1954) postulates that the difficulty of an aiming movement can
65 be measured using the same metric as in an artificial information system. The author
66 describes the relationship between the ratio of the distance of a target to the width of the
67 target and movement time (MT): $MT = a + b \times \log_2(2A/W)$ where a and b are em- pirical
68 constants, A is the amplitude of the motion and W is the width of the target. In this
69 expression, $\log_2(2A/W)$ corresponds to the index of difficulty of the task (ID). Fur- thermore,
70 in analogy with Shannon and Weaver's informa- tion theory, Fitts predicts that the
71 information processing capacity of the human motor system illustrates the perfor- mance
72 index (PI). The measurement of the PI is a relevant parameter as it gives a glimpse into how
73 the subject behaves facing two opposite constraints, namely speed and accura- cy of

74 movement. Thus, when the accuracy of a movement needs to be preserved, movement time
75 increases based on the task's constraints and, thus, its level of difficulty, the in-
76 dividuals' task PI is reduced.[12,15] This law applies to most human movements, including the fine
77 movements neces- sary to perform daily activities such as tying one's shoelaces or using a
78 computer mouse.[16]

79 The results measured around a Fitts task can be generalized to pointing and manual
80 movements, as well as those involving the use of tools in daily life.[17] For these reasons, the
81 execution and evaluation of the Fitts task allows us to assess the impact of many variables on
82 an individual's fine motor skills, motor performance, accuracy, and time of movement.[18]
83 Fitts' law has been widely used in clinical re- search to assess the impact of different
84 treatments or symp- toms on the fine motor performance of individuals.[19] A recent study
85 suggests that, in young adults, intensive acute aerobic exercise reduces MT, an important
86 component of motor performance, when performing a discrete aiming task.[20] These results
87 as well as the popularity of the Fitts' law paradigm in other disciplines argue for its continued
88 investigation in order to analyze the effect of exercise on human motor behavior.[20]

89

90 **AIM**

91 To our knowledge, no study has examined the effect of PAL on individuals' fine motor
92 performance performed using a reciprocal aiming task. The objective of this study was to ex-
93 amine the relationship between the amount of daily PA and the PI of healthy adults while
94 performing a fine motor task.

95

96 **MATERIALS AND METHODS**

97

98 **Population**

99 Volunteers were recruited from the Institut Limousin de Formation aux Metiers de la
100 Réadaptation and the campus of Medicine and Pharmacy, University of Limoges. Partici-
101 pants had to be 18 years old or younger, working or study- ing at the University of Limoges,
102 able to read and under- stand French, and willing to participate in the study. They were
103 excluded if any impairments could interfere with the motor task. They were informed of the
104 different steps of the study and gave their informed consent in writing, in accordance with the
105 Declaration of Helsinki.[21] This study was divided into two parts: the first part aimed to
106 assess the participants' PAL and the second part consisted in per- forming the reciprocal Fitts
107 task.

108

109 **Measurement of PAL**

110 Physical activity levels are determined using the Global Physical Activity Questionnaire
111 (GPAQ).[22] This ques- tionnaire, developed by the World Health Organization, is composed
112 of 16 items to assess the duration and the fre- quency of PA in three dimensions: leisure
113 activities, work activities, and travel.[23] The GPAQ distinguishes PA dura- tion by min/day
114 and min/week for each PA domain, which allows for calculating the energy expenditure
115 scored in metabolic equivalent tasks (METs). Based on duration and energy expenditure, PAL
116 was classified as low, moderate, and high. Prior to the completion of the motor task, partic-
117 ipants were invited to answer the GPAQ self-questionnaire using the Google form platform,
118 under the supervision of a researcher to clarify any misunderstanding. Answers were assigned
119 to anonymous identification numbers (e.g., S01, S02, (...), S90) and then recorded on a
120 computer.

121 The analysis of this questionnaire, using different for- mulas by the user manual of the
122 questionnaire, allowed to calculate a continuous index of individual PAL and distin- guish
123 three groups[23]: Group 1: people with a high level of physical activity (individuals who
124 participate in intense PA at least 3 days per week, resulting in an energy expendi- ture of at
125 least 1500 MET-min per week, or at least 7 days of moderate or intense walking and PA until
126 a minimum of 3000 MET-min per week is reached); Group 2: people practicing regular PA in
127 a moderate way (individuals who do not qualify for the criteria in the previous category, but
128 who participate at least 20 minutes of intense PA per day for 3 or more days per week or 30
129 minutes of moderate PA or walking per day for 5 or more days per week, or at least 5 days of
130 walking and moderate or intense PA, until achiev- ing a minimum of 600 MET-min-week),
131 and Group 3: peo- ple with a low level of PA (individuals who do not meet any of the above
132 criteria).

133

134 **Motor task**

135 **Apparatus and task**

136 Participants sat at a table facing a laptop screen aligned at eye level. A graphics tablet
137 (Wacom Cintiq Pro 13") was placed horizontally on the table directly in front of them and
138 connected to the computer. Participants had to move a red cursor (represented by a vertical
139 line) as quickly and accurately as possible back and forth between two vertical white bars
140 displayed on either side of the computer screen. The left-right sliding movements of a pen on
141 the surface of the graphics tablet resulted in the left-right movement of a cursor on the screen,
142 controlled by a dedicated software developed at Aix-Marseille University, running on the lap-
143 top computer connected to the graphics tablet (Fig. 1). The position of the pen on the graphics
144 tablet was sampled at a frequency of 150 Hz. The cursor position on the screen was
145 reconstructed from the pen position data.



Figure 1. Motor task.

146

147

148 **Procedure**

149 The reciprocal aiming task was performed under four lev- els of difficulty. Following Fitts’
150 law[12], task difficulty was defined through an Index of Difficulty [$ID = \log_2(2D/W)$], where
151 D is the distance between target centers and W is the target width, or tolerance size. D was
152 constant for all experimental conditions (25 cm). ID was thus manipulated by varying targets
153 size (W). Sizes were 6.25 cm, 3.125 cm, c1.562 cm, and 0.781 cm for ID3, ID4, ID5 and ID6,
154 respectively.

155 Participants first performed a familiarization trial (at level 3, the easiest) to ensure the
156 understanding of the in- structions. The four experimental conditions (ID3 to ID6) with both
157 hands were performed in a randomized order.

158 Each trial consisted of 25 cycles, for a total of 50 aiming movements per level per hand (200
159 movements per side).

160

161 **Data analysis**

162 The position time series were filtered with a dual-pass, sec- ond-order Butterworth filter, with
163 a cut-off frequency of 8 Hz. Analysis focused on global measures such as MT, the PI, and the
164 error rate (Err). MT was defined as the average half cycle time, from one spatial movement
165 extremum (i.e., reversal point) to the next. The Err was defined as the num- ber of movement
166 reversal outside targets limits. In order to compute the PI, the effective width of the target
167 (We) was defined as 1.96 times the standard deviation of the actual end-point distribution at
168 movement reversal.[24] The PI was computed from MT and the effective Index of Difficulty
169 (IDe) according to the International Organization for Stan- dardization[25] as the following:

170 PI = IDE/MT where IDE is the effective index of difficulty adjusted by using effective width
171 of the target and computed as: $IDE = \log_2(2D/We)$. All measurements were carried out for the
172 two-handed conditions (DH and NDH) and for each level of Index of Difficulty.

173

174 **Statistical analysis**

175 Statistical analyses were carried out using R Studio (ver- sion 4.04, Integrated Development
176 Environment for R, PBC, Boston). Gaussian distribution was verified using the Shapiro-Wilk
177 test: due to an absence of normal dis- tribution, non-parametric statistical analyses were
178 priori- tized. Spearman correlations were performed between our variables of interests:
179 Performance Index (PI), movement time (MT) and error rates (Err), and the continuous index
180 of individual PAL. These correlations were performed for the four levels of difficulty of the
181 task (ID). To verify the application of Fitts' law to our motor task, a linear regres- sion was
182 conducted for MT, as a function of the difficulty index. NparLD tests were performed using
183 the nparLD package.[26] The between-groups variable (subject group of PAL) and the
184 within-groups variable (task difficulty in- dex) were analyzed to determine the main effects as
185 well as the interactions on the outcome variables listed above. Relative treatment effect
186 (RTE) was used as a measure of effect with the following interpretations and a RTE value lies
187 between 0 and 1. An RTE of 0.5 means no effect (a randomly selected participant from the
188 whole sample has a 50/50 chance of achieving a lower score on an outcome measure than a
189 randomly selected participant from either subgroup). An $RTE < 0.5$ indicates a tendency for
190 partici- pants in a subgroup to score lower than a randomly se- lected participant in the full
191 sample, conversely when a $RTE > 0.5$. Differences were considered small, medium or large
192 when $RTE \geq 0.56$, 0.64 or 0.71, or ≤ 0.44 , 0.36, and 0.29, respectively.[27] Post-hoc tests were
193 carried out using the same nparLD method, to make matched comparisons between our
194 groups.

195

196 **RESULTS**

197 Ninety volunteers participated in the experiment pro- posed in this study. However, due to
198 incomplete regis- trations, three participants were not included. Thus, 87 healthy adults
199 (28.5 ± 10.5 years old, 63 women) were in- cluded. Participants characteristics are summarized
200 in Table 1.

201

202 **Motor task**

203 **Performance index**

204 No correlation between index of individual PAL and PI was observed ($r=0.07$, $p=0.052$).
205 However, the analysis revealed a low positive correlation (Fig. 2a) between the PAL index
206 and PI at level 3 ($r=0.23$, $p=0.002$).

Table 1. Participants' characteristics

	Participant (n=87)
Sex (men/women)	24/63
Age (years): mean \pm SD	28.5 \pm 10.5
Hand dominance (left/right)	9/78
PA level (Kcal): mean \pm SD	2079 \pm 2360
PA level: frequency (proportion)	
PA High (Group 1)	26 (29.89)
PA Moderate (Group 2)	29 (33.33)
PA Low (Group 3)	32 (36.78)

PA: Physical activity; SD: Standard deviation

207

208 The non-parametric longitudinal analyses revealed a non-significant group effect on PI
 209 ($F(2;\infty)=1.13$; $p=0.57$; RTE=0.53 for group 1, RTE=0.48 for group 2, RTE=0.50 for group 3)
 210 (Table 2). A main effect of index of difficulty (ID) was also found ($F(3;\infty)=570.9$; $p<0.000$;
 211 RTE=0.76 for the ID3, RTE=0.56 for ID4, RTE=0.39 for the ID5, RTE=0.27 for ID6) (Table
 212 2).

Table 2. NparLD analysis results

	PI	MT	Errors rate
Group effect, DF = 2			
F (p-value)	1.13 (0.57)	3.18(0.20)	9.40 (0.009)
RTE:			
Group 1	0.53	0.46	0.57
Group 2	0.48	0.52	0.47
Group 3	0.50	0.51	0.47
ID effect, DF = 3			
F (p-value)	570.9 (<0.00)	1699.73 (<0.00)	239.88 (<0.000)
RTE			
ID3	0.76	0.18	0.19
ID4	0.56	0.38	0.40
ID5	0.39	0.62	0.62
ID6	0.28	0.82	0.79
Interaction Group*ID, DF = 6			
F (p-value)	6.50 (0.37)	5.70 (0.46)	16.73 (0.01)
RTE (group*ID)			
1*3; 1*4	0.81; 0.61	0.15; 0.33	0.22; 0.49
1*5; 1*6	0.41; 0.27	0.57; 0.78	0.71; 0.86
2*3; 2*4	0.74; 0.51	0.19; 0.42	0.15; 0.36
2*5; 2*6	0.39; 0.27	0.64; 0.85	0.59; 0.78
3*3; 3*4	0.72; 0.57	0.20; 0.40	0.20; 0.36
3*5; 3*6	0.39; 0.30	0.63; 0.82	0.56; 0.75

PI: index of performance; MT: movement time; ID: index of difficulty; Group: group of PA level; F: statistic, significant p-value at $p<0.05$;
 RTE: relative treatment effect; DF: degree of freedom.

213

214

215 Movement time

216 A negative correlation between the continuous index of individual PAL and movement time
 217 (MT) was observed ($r=-0.12$, $p<0.002$) (Fig. 2b), regardless of the difficulty level of the
 218 task ($r=-0.28$, $p<0.001$; $r=-0.25$, $p<0.001$; $r=-0.16$, $p=0.004$; $r=-0.21$, $p=0.03$; for the ID3,
 219 ID4, ID5, and ID6,

220 respectively). The ID also correlated positively with move- ment time ($r^2=0.69$; $p<0.000$). No
 221 effect of the group of PAL was found on the MT ($F(2;\infty)=3.18$; $p=0.20$).
 222 The nparLD analysis revealed a main effect of the index of difficulty on MT ($F(3;\infty)=1699$;
 223 $p<0.000$; RTE=0.18 for the ID3, RTE=0.38 for ID4, RTE=0.62 for the ID5, RTE=0.82 for
 224 ID6) (Table 2).

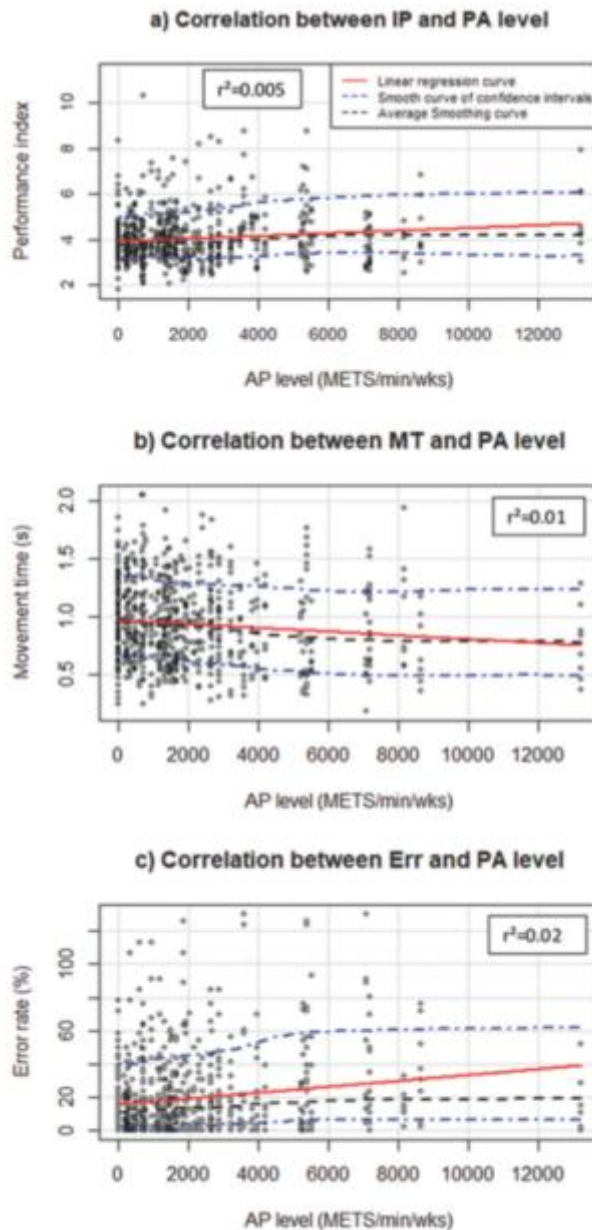


Figure 2. Correlations between the continuous index of individual PAL and variables of interest: Performance Index (a), Movement time (b), and Error rate (c).

225

226

227 Error rate

228 A positive correlation between the PAL index of partic- ipants and their Error rates (Err) was
 229 observed ($r=0.15$, $p<0.000$) (Fig. 2c). Correlations were observed at ID 4, 5 and 6
 230 (respectively $r=0.27$, $p<0.001$; $r=0.32$, $p<0.000$ and $r=0.32$, $p<0.000$).

231 The NparLD analysis revealed a small significant ef- fect of the group of PAL index on Err
 232 ($F(2;\infty)=9.4$; $p=0.009$; RTE=0.57 for group 1, RTE=0.47 for group 2, RTE=0.47 for group 3).

233 Participants with a high level of PA made, on average, more errors (25.8±2.5%) than those
234 with moderate (16.1±2.3%) and low levels of PA (17.011%±2.213%). No differences were
235 shown between moderately and low active subjects (Table 2). A main effect of index of
236 difficulty (ID) was also found ($F(3;\infty)=23.88$; $p<0.000$; RTE=0.19 for the I3, RTE=0.40 for
237 ID4; RTE=0.61 for the ID5, RTE=0.79 for ID6). The correlation between Err and ID
238 indicated that when difficulty increases, so do the individuals' error rates (Table 2).

239 An interaction exists between PAL and difficulty index ($F(6;\infty)=16.73$; $p=0.01$; RTE=0.22,
240 0.48, 0.70, 0.85 for group 1 and the ID 3, 4, 5, and 6, respectively; RTE=0.15, 0.36, 0.59,
241 0.78 for group 2 and the 4 ID, respectively; RTE=0.20, 0.37, 0.56, 0.75 and for group 3 and
242 the ID 3, 4, 5 and 6, respectively) (Table 2).

243

244 **DISCUSSION**

245 To our knowledge, this study is the first to determine the influence of PAL on individuals'
246 fine motor performance using a reciprocal aiming task. Apart from a correlation between PAL
247 and individuals' motor performance when the constraints of a reciprocal aiming task were
248 lowest (i.e., ID3), this study did not show an influence of participants' daily PAL on their PI.

249

250 **Level of physical activity**

251 **Motor performance**

252 Our results indicated that the continuous index of level of PA was positively correlated with
253 the PI achieved when performing a Fitts task on a tablet when the ID was 3. On a reciprocal
254 aiming task, when the constraints imposed by the task are minimal (i.e., low ID), the
255 movement is cyclic and continuous, and the deceleration and acceleration phases are fully
256 merged. If the ID of the task increases, the motion becomes a concatenation of discrete
257 movements, and the movement tends towards a more accurately constraining goal.[28] The
258 kinetic energy created by the initial acceleration of the motion is dissipated during the final
259 braking phase.[29] Thus, at ID3, the individual has a greater variability allowed by relatively
260 low constraints (a greater width of targets). It is possible that these results reflect differences
261 in behavior and performance between subjects that are not identifiable at ID4, 5, and 6.
262 However, the correlation is weak and other parameters should be considered in the analysis.

263 Many activities of daily living, such as walking, do not require great precision. Conversely,
264 many sedentary activities require the production of fine and accurate movements. Computer
265 games, for example, have a positive influence on the motor skills of young adults,
266 particularly about the precision and speed of arm and hand movements.[30] Profession- al
267 musicians, on the other hand, can learn motor sequences faster and more accurately than non-
268 musicians.[31] It is possible that participants with music-related activity can adapt more
269 easily to fluctuating levels of difficulty, providing an adapted motor response more quickly

270 and accurately than other subjects. Thus, it would also be important to consider the sedentary
271 activities performed by the participants.

272

273 **Error rate**

274 Concerning the accuracy of movements produced, we observed that physically active
275 participants are less accurate when the task becomes more difficult. Fitts' law suggests that
276 the less accurate a subject is, the faster they are. Also, we can suggest that if they are less
277 accurate, very physically active people should move faster than low or moderately active
278 person. Nevertheless, our results do not indicate any significant effect of PAL on MT. In
279 addition to the influence of PAL on individuals' performance on fine motor skills, these
280 results may illustrate the impulsivity of some subjects compared to others who are more
281 cautious. Kekäläinen et al.[32] support this hypothesis. Using NEO-Personality Inventory-
282 33, the authors showed that the impulsivity facet had one of the strongest associations with
283 physical activity.[32]

284

285 **Index of difficulty**

286 The task difficulty index had a significant effect on the participants' PI, MT, and Err. The
287 MT of the three groups (i.e., the high, moderate, and low physical activity groups) increased
288 linearly according to Fitts' law.[12] The PI, which is the product of the ratio between the MT
289 and the ID, and accuracy were altered. These results are consistent with those found in the
290 literature.[13,33] The task performed by the participants thus complied with Fitts' law.

291

292 **Strengths and limitations**

293 Despite the number of participants, the sample size for each PAL was approximately 30
294 individuals. In addition, the study sample was primarily female and students under the age of
295 25. It would be interesting to replicate this study with a more heterogeneous population.
296 Furthermore, due to temporal limitations, only the GPAQ questionnaire could be used to
297 measure participants' daily PAL. Nevertheless, the combination of measurement instruments,
298 which is widely recommended today, and should be sought[34], would have made it possible
299 to evaluate physical and sedentary activities in all their complexity, with qualitative and
300 quantitative information.[35]

301 The overall strength of this work is to identify the benefits of using an aiming task and a
302 digital tablet in a clinical setting. According to the literature, it seems that the results
303 measured around a Fitts task can be generalized for pointing and manual movements as well
304 as those involving the use of tools in daily living: pen, cutlery, needle, screwdriver, which are
305 of interest to occupational therapists.[17] Thus, it could be interesting to perform Fitts' tasks
306 in a clinical setting. The use of a digital tablet could also be interesting to evaluate the

307 quality of movements. While several measures of movement quality have been developed,
308 these quality measures depend mainly on the clinician's experience.[36] The use of this tablet
309 allows us to reflect the motor functioning of individuals and to objectively assess the quality
310 of fine movements of individuals with different movement disorders, such as Parkinson's
311 disease or developmental coordination disorders, an assessment that until now has been
312 difficult for clinicians.

313

314 **CONCLUSIONS**

315 To our knowledge, this study is the first to determine the influence of daily physical activity
316 on individuals' fine motor performance using a reciprocal aiming task. The results of our
317 study didn't indicate any significant major correlation between daily PAL and PI or an effect
318 of the group of PAL on the performance index achieved by the participants. The next step will
319 be to consider the use of Fitts' reciprocal task and a digital tablet in a clinical setting.

320

321 **Acknowledgements**

322 We are thankful to the Mission pour l'Interdisciplinarity Team, Défi CNRS AUTON for their
323 scientific insight and unyielding support.

324

325 **Declaration of conflicting interests**

326 The authors declare that there is no conflict of interest.

327

328 **Funding**

329 The authors received no financial support for the research, authorship, and/or publication of
330 this article.

331

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