

Supplementary material

Table S1. Summary of previous studies on the effects of regular physical activity on creative thinking: Interventional studies

| | Subjects | Design | Exercise intervention | Control intervention | Findings | | | |
|--|--|---|--|---|-------------------------------------|--|---|--|
| | | | | | Divergent thinking: AUT | Divergent thinking: other tests | Convergent thinking | Other findings on exercise and/or creativity |
| Gondola & Tuckman 1985 | Students | Quasi-experimental : Ex vs Con at post-test | n=26; 20-min running, twice a week, 8 weeks | n=23; Health education lecture | Fluency: ↑ | Remote Consequences: ↑ | Matchsticks: ns | - |
| Gondola 1986 | College students | Quasi-experimental : Ex vs Con at post-test | Spring Exercise: n=23; 20-min running, twice a week, 8 weeks Summer Exercise: n=19; 20-min running, twice a week, 6 weeks | Control: n, unreported; health/fitness-oriented class without any physical activity in Spring | Fluency: ↑ for both Exercise groups | Remote Consequences: ↑ for Summer Exercise only | Matchsticks: ns between Spring Exercise and Control | Fitness (1.5-mile run): ↑ for both Exercise groups |
| Tuckman & Hinkle 1986 | 4-6 th grade students (n=154) | RCT: Ex vs Con at post-test | 30-min running, three times a week, 12 weeks | Regular physical education, including basketball, volleyball, and occasional jogging | Fluency: ↑ | - | - | Intervention*Sex interaction on AUT: ns Intervention*Grade interaction on AUT: ns Fitness (800-m run): ↑ |
| Hinkle et al., 1993 | 8 th grade students (n=85) | RCT: Ex vs Con % post-pre change | Running, five times a week, 8 weeks | Regular physical education, including badminton, table | - | TTCT: Figural fluency ↑ Figural flexibility ↑ Figural originality ↑ | - | Intervention*Grade interaction on TTCT: ns Fitness (800-m run): ↑ Mood and self-esteem |

| | | | | | | | | |
|--|--|---------------------------------------|---|--|---|--|---|--|
| | | | | tennis, volleyball | | Figural elaboration <i>ns</i> Verbal fluency <i>ns</i> Verbal flexibility <i>ns</i> Verbal originality <i>ns</i> | | related measures: <i>ns</i> Significant sex difference in figural elaboration, verbal originality: Female > Male |
| Herman-Tofler & Tuckman 1998 | 3 rd grade students (<i>n</i> =52) | RCT: Ex vs Con at post-test | 25-min aerobics with energetic music, three times a week, 8 weeks | Regular physical education about various racket sports, including practice | - | TTCT: Figural fluency ↑ (<i>d</i> =0.71) Figural originality <i>ns</i> Figural elaboration <i>ns</i> | - | Fitness (800-m run): <i>ns</i> Self-perception of athletic competence, social acceptance, global self-worth, etc.: <i>ns</i> |
| Pedro Ángel et al., 2021 | 3 rd -6 th grade students (<i>n</i> =140) | RCT: Ex vs Con group*time interaction | 30-min active recess program, three times a week, 10 weeks | No intervention | - | PIC-N: Narrative fluency ↑ Narrative flexibility ↑ Narrative originality ↑ Graphic design ↑ Graphic shadow and color ↑ Graphic details <i>ns</i> | - | School aptitudes: ↑ Cognitive flexibility (TMT-B): ↑ Correlation between improvement in cognitive flexibility and improvement in VO ₂ max (<i>r</i> =-0.29*) |

AUT: Alternate Uses Test; **TTCT:** Torrance Tests of Creative Thinking; **PIC-N:** Prueba de Imaginación Creativa – Niños *ns*: nonsignificant.

Literature search strategy: *database:* Pubmed; *search field:* Title/Abstract; *search terms:* (exercise OR physical activity OR walking OR running OR cycling OR aerobic training OR fitness training OR resistance training) AND (regular OR habit OR program OR chronic OR days OR week OR month) AND (creativity OR divergent thinking OR convergent thinking OR Alternate Uses OR Guilford OR Torrance OR remote associates test OR cognitive flexibility OR analogy OR insight problem solving OR metaphors); *last search and confirmation date:* 2021/07; a cross-reference search was also conducted. *d:* Cohen's *d*. *r:* correlation coefficient. **p*<0.05. In addition to the studies listed here, we also found another interventional study that evaluated creative thinking in terms of creating analogies using the Similarities subtest of the Wechsler Adult Intelligence Scale-Revised (Kamegaya, T., Araki, Y., Kigure, H., Long-Term-Care Prevention Team of Maebashi City, & Yamaguchi, H. (2014). Twelve-week physical and leisure activity programme improved cognitive function in community-dwelling elderly subjects: a randomized controlled trial. *Psychogeriatrics*, 14(1), 47-54.).

Table S2. Summary of previous studies on the effects of regular physical activity on creative thinking: Observational studies

| | Subjects | Design | Regular physical activity measures | Creative thinking measures | Findings: association between regular physical activity and creative thinking | Other findings on physical activity and/or creativity |
|---|-----------------------------------|-----------------|---|--|--|---|
| Cavallera et al. 2011 | University students ($n=61$) | Cross-sectional | Self-reported number of hours of sport activity per week | Divergent thinking: TTCT figural series | Elaboration: correlation coefficient $r=0.31^*$ Fluency: <i>ns</i> Flexibility: <i>ns</i> Originality: <i>ns</i> | Morningness-eveningness personality did not affect the association |
| Rominger et al., 2020 | University students ($n=79$) | Cross-sectional | ActiGraph®, over 5 consecutive days | Divergent thinking: Combined measure of AUT originality and TTCT figural originality | Total everyday bodily movement: correlation coefficient $r=0.32^{**}$ No to light activity: $r=-0.29^*$ Moderate activity: $r=0.26^*$ Vigorous activity: $r=0.15$, <i>ns</i> Very vigorous activity: $r=0.20$, <i>ns</i> | Positive-activated affect did not mediate the association between everyday bodily movement and creativity |
| Nakagawa et al., 2020 | Young adults ($n=49$) | Cross-sectional | IPAQ-short: days of walking, moderate, and vigorous intensity physical activity | Convergent thinking: Insight problem solving (matchsticks, nine-dot puzzle, and coin puzzle) | <i>ns</i> (regression model including all three regular exercise measures as independent variables) | Moderate intensity physical activity predicted working memory and coping strategies Vigorous intensity physical activity predicted coping strategies and psychological wellbeing |
| Piya-amornphan et al., 2020 | Students of age 6-17 ($n=1447$) | Cross-sectional | TPACS-SQ: Number of days with at least 60 min of active play in the past week | Divergent thinking: TCT-DP | Age 6-9 years: $r=0.010$, <i>ns</i> Age 10-13 years: $r=0.014$, <i>ns</i> Age 14-17 years: $r=0.148^{**}$ | No correlation between creativity and time spent with family and peers for all age groups No correlation between creativity and time in sedentary behavior for all age groups |

AUT: Alternate Uses Test; TTCT: Torrance Tests of Creative Thinking; TCT-DP: Test for Creative Thinking-Drawing Production; TPACS-SQ: Thailand Physical Activity Children Survey-the Student Questionnaire; r : correlation coefficient. *ns*: nonsignificant. $*p<0.05$, $**p<0.01$. We also identified two additional cross-sectional study (Rominger, C., Papousek, I., Fink, A., Perchtold, C. M., Lackner, H. K., Weiss, E. M., & Schwerdtfeger, A. R. (2019). Creative challenge: Regular exercising moderates the

association between task-related heart rate variability changes and individual differences in originality. Plos one, 14(7), e0220205; Jung, M., Kim, H. S., Loprinzi, P. D., & Kang, M. (2021). Serial-multiple mediation of enjoyment and intention on the relationship between creativity and physical activity. AIMS neuroscience, 8(1), 161.). [Rominger et al., 2019](#) tested a regression model including task-related HRV change, the amount of regular exercise, and their interaction as independent variables to predict AUT originality and found that the amount of regular exercise moderated the association between task-related HRV change and originality. [Jung et al., 2021](#) employed the Kaufman Domains of Creativity Scale (K-DOCS) measuring creative behavior in the domains of self/everyday creativity, scholarly creativity, performance creativity, mechanical creativity, and artistic creativity. This study reported a positive correlation between the amount of PA per week and total creativity ($r=0.60$, $p<0.01$).

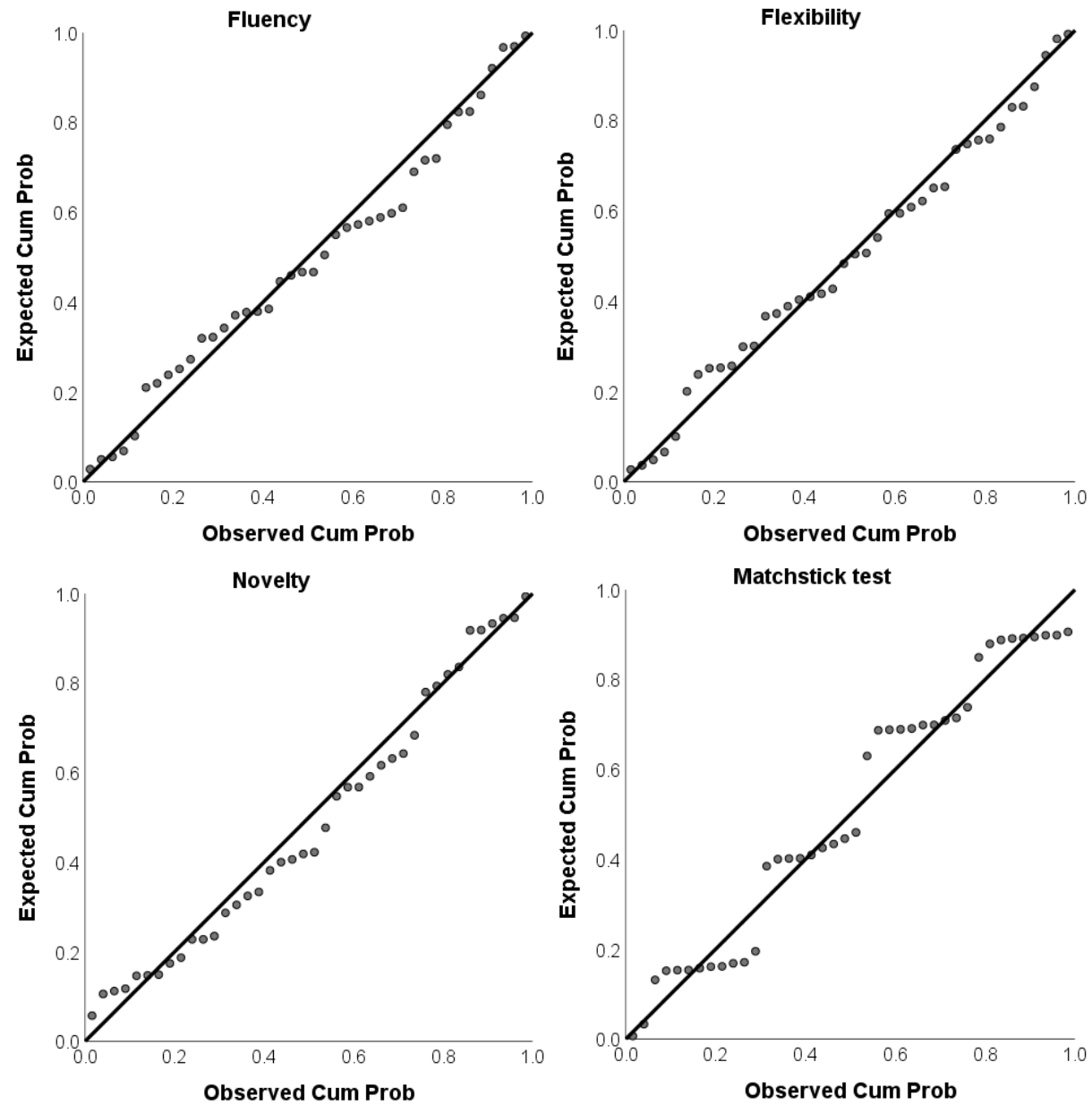
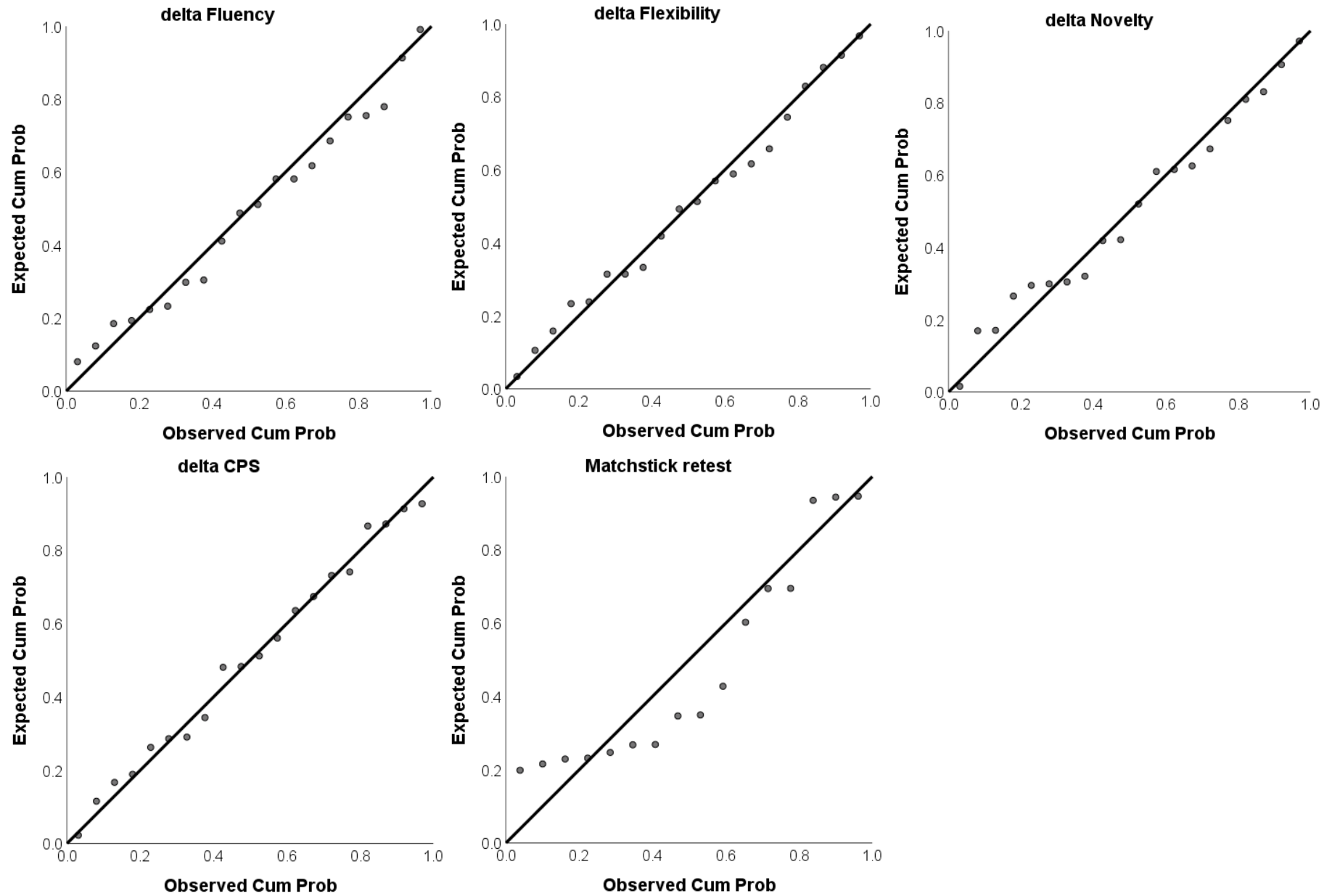


Figure S1. Normal P-P plot of regression standardized residual of multiple linear regressions shown in Table 1.

Exercise



Control

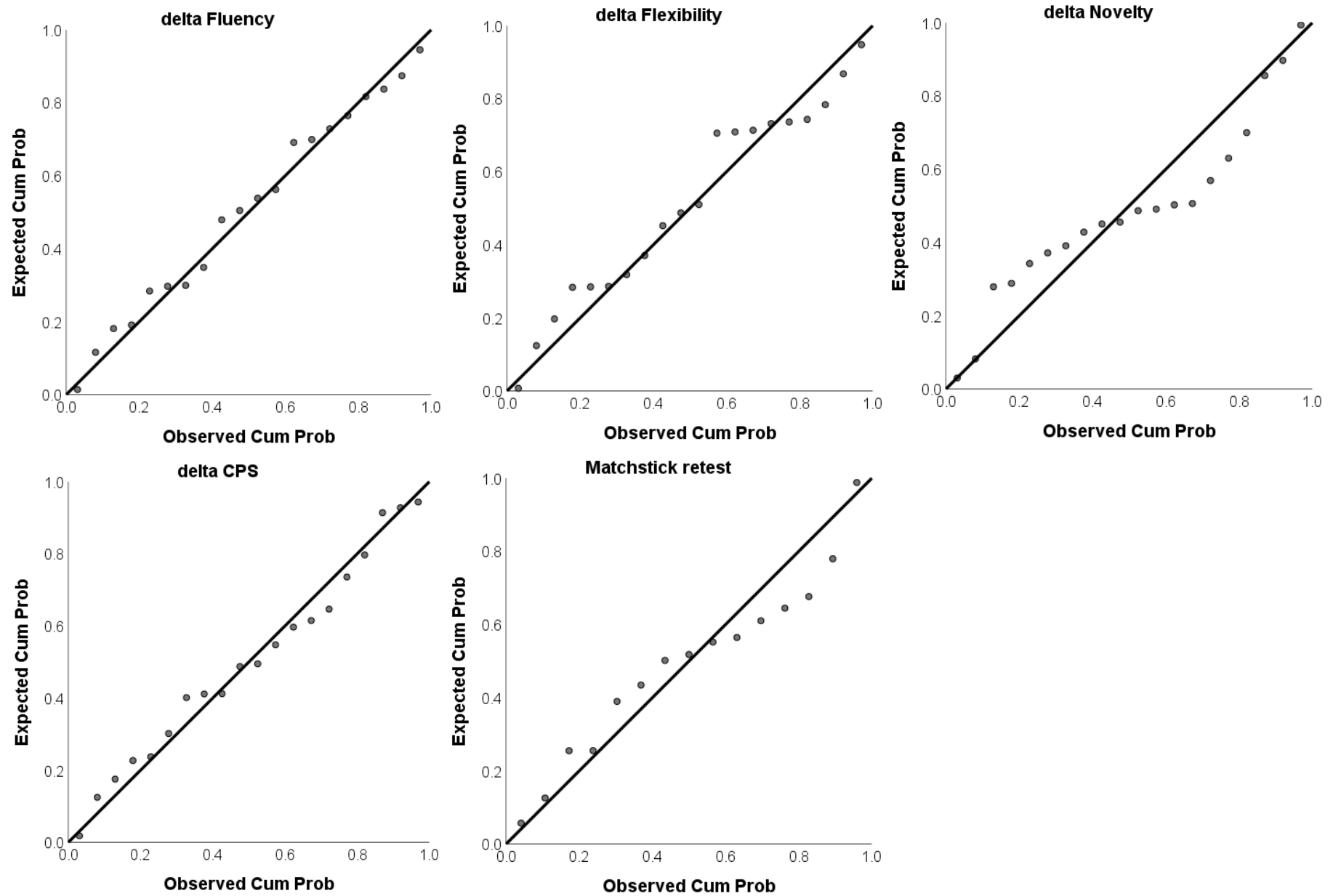


Figure S2. Normal P-P plot of regression standardized residual of multiple linear regressions shown in Table 2.

Table S3. The unstandardized coefficients and their 95% Confidence Intervals for multiple linear regressions shown in Table 1.

| Dependent variables | | Divergent thinking (AUT) | | | Convergent thinking |
|-----------------------|----------|----------------------------|----------------------------|----------------------------|-----------------------|
| | | Fluency | Flexibility | Novelty | Matchstick pre-test |
| Independent variables | Vigorous | 0.007(0.001, 0.012) | 0.006(0.001, 0.011) | 0.002(0.000, 0.005) | 0.00006(0.000, 0.000) |
| | Moderate | 0.000(-0.004, 0.004) | 0.001(-0.003, 0.004) | 0.001(-0.002, 0.003) | -0.00002(0.000,0.000) |
| | Walking | 0.005(-0.001,0.011) | 0.005(0.000, 0.011) | 0.004(0.001, 0.007) | -0.00004(0.000,0.000) |

Table S4. The unstandardized coefficients and their 95% Confidence Intervals for multiple linear regressions shown in Table 2.

| Dependent variables | | Divergent thinking (AUT) | | | Convergent thinking | |
|-----------------------|----------|--------------------------|-----------------------|-------------------------|-------------------------|---------------------------|
| | | ΔFluency | ΔFlexibility | ΔNovelty | ΔCPS | Matchstick retest |
| Exercise group | | | | | | |
| Independent variables | Vigorous | -0.005(-0.018, 0.008) | -0.003(-0.014, 0.008) | -0.002(-0.008, 0.004) | 0.000(-0.001, 0.001) | 0.001(-0.001, 0.002) |
| | Moderate | -0.001(-0.008, 0.006) | -0.001(-0.007, 0.005) | 0.000(-0.004, 0.003) | 0.000(0.000, 0.001) | 0.00005(-0.001,0.001) |
| | Walking | -0.002(-0.013, 0.010) | -0.001(-0.010, 0.009) | -0.002(-0.007, 0.004) | -0.00007(-0.001,0.001) | -0.001(-0.002, 0.001) |
| Control group | | | | | | |
| Independent variables | Vigorous | -0.002(-0.008, 0.004) | -0.003(-0.008, 0.003) | -0.002(-0.006, 0.003) | 0.000(-0.001, 0.000) | 0.000(-0.001, 0.001) |
| | Moderate | 0.003(-0.002, 0.008) | 0.002(-0.003, 0.007) | -0.00009(-0.004, 0.007) | -0.00004(-0.001, 0.001) | 0.001(0.000,0.001) |
| | Walking | -0.002(-0.009, 0.005) | -0.003(-0.009, 0.004) | -0.003(-0.009, 0.002) | 0.000(-0.001, 0.000) | -0.001(-0.001,0.000) |