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Title: Carbohydrate mouth rinse during physical activity to improve cognitive function: A randomized cross-over trial

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Abstract

The dorsolateral prefrontal cortex (DLPFC) is a brain region responsible for executive function. Recent studies have reported that low-intensity physical activity (LPA) can activate this region and improve executive function. Carbohydrate mouth rinse (CMR), an ergogenic conditioning method in sports science, has been shown to activate the DLPFC. This study hypothesized that LPA-induced improved executive function could be synergistically enhanced by CMR. We investigated the impact of combining LPA with CMR to improve executive function.

Seventeen healthy university students (eight males, nine females) participated. For LPA, instead of commonly-used exercise modalities, such as bicycle ergometers or treadmills, we employed a seated dual-task exercise (DE) that involved performing cognitive tasks and physical activity simultaneously, which is considered effective for cognitive function. Four trials were conducted using a crossover design: trial 1 control (CON), trial 2 (CON+CMR), trial 3 (DE), and trial 4 (DE+CMR). The Trail Making Test Type B (TMT-B, Japanese version) and Stroop Test (ST, Japanese version) assessed cognitive function, and CMR was administered with a 6% glucose solution four times during CON and DE.

The results indicated a significant interaction in Interference Rate I of the ST, showing improved performance due to DE. An interaction was also observed in Interference Rate II, highlighting enhanced performance when DE was combined with CMR. Although no interaction was found in the TMT-B, a pre-post comparison revealed improved performance in the DE + CMR trial.

These findings suggest the potential for further improvement in executive function when DE is combined with CMR.

Keywords: carbohydrate, sedentary behavior, dual-task exercise, cognitive function

論文名

デュアルタスク運動とマウスリンスの併用が認知機能に及ぼす影響（ランダム化比較試験：クロスオーバーデザイン）

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抄録

背外側前頭前野（DLPFC）は実行機能を司る脳領域であり、近年では低強度身体活動(LPA)でもDLPFCが活性化し、実行機能向上に効果的であることが報告されている。一方、炭水化物マウスリンス（CMR）は、近年スポーツ科学分野で用いられるようになったエルゴジェニックなコンディショニング法であり、口に炭水化物水溶液を含むだけで、DLPFC を活性化することが明らかにされている。そこで、本研究では LPA に CMR を介入すれば更なる実行機能向上が見られると仮説を立て、LPA に CMR を組み合わせることで実行機能の向上に及ぼす影響について明らかにすることを目的とした。対象は健康な大学生 17 人（男性 8 人、女性 9 人)。LPA としては一般的に用いられる自転車エルゴメーターやト

レッドミルではなく、運動と認知課題を同時に行うことで認知機能向上に効果的と言われている座位姿勢デュアルタスク運動（DE）を採用し、以下の 4 試行をクロスオーバー法で実施した（試行 1 コントロール（CON)、試行 2 CON+CMR、試行 3 DE、試行 4 DE+CMR)。認知機能検査には日本語版の Stroop Test（ST）と Trail Making Test Type B（TMT-B）を用いた。CMR には 6%グルコース水溶液を用いて CON と DE 試行中に全 4 回実施した。ST の干渉率Ⅰでは交互作用が認められ、DE による成績向上が認められた。また、干渉率Ⅱでは交互作用が認められ（$p<0.010$)、DE と CMR を組み合わせるによる成績向上が認められた。また、TMT-B では交互作用が認められなかったが、前後比較では DE+CMR 試行で成績向上が認められた（$p<0.001$)。

　これらのことから、DE中にCMRを組み合わせることで更なる実行機能向上の可能性が示唆された。

Introduction

The 2020 WHO guidelines state that any form of physical activity (PA) is beneficial for health even when performed for short durations. Additionally, owing to the adverse health effects of prolonged sitting, it is recommended to perform PA of any intensity, including light-intensity.[1)] Performing regular PA has been shown to improve physical health, alleviate symptoms of depression and anxiety, as well as enhance mental health and cognitive function.[1,2)]

The effects of acute PA interventions on cognitive function have been reported in several previous studies.[3-7)] As an intervention mechanism, PA has been shown to activate the primary motor cortex, supplementary motor area (SMA), parietal lobe (PL), and areas of the frontal lobe, including the dorsolateral prefrontal cortex (DLPFC)—one of the brain regions involved in cognitive activities.[3,4,8)] Specifically, the DLPFC is responsible for executive functions.[9)] Executive functions refer to the processes necessary for the planning, action, and thinking required to achieve goals. Elements that constitute executive functions include inhibition, working memory, and cognitive flexibility.[10)] Therefore, since the DLPFC is crucial for performing executive functions, its activation is key to improving cognitive function.

Students today spend prolonged periods sitting in classrooms, necessitating strategies such as replacing this time with PA.[11)] Programs such as Physical Activity Across the Curriculum (PAAC) and Take10! have been developed and implemented as optimal PA interventions in the classroom, resulting in reported educational benefits and improved cognitive function.[12,13)] However, concerns have been raised about preparing an appropriate space for these activities in the classroom.[11)]

One easily accessible form of light-intensity physical activity (LPA) is dual-task exercise (DE), which involves performing two tasks simultaneously, such as cognitive tasks and LPA. Since both LPA and cognitive tasks induce brain activation, combining them enhances cognitive function.[14)] Studies targeting older adults have reported numerous benefits of DE on cognitive function.[15-17)] However, research on the effects of DE on cognitive function in young people is limited.[18-20)]

Carbohydrate mouth rinse (CMR) has emerged as an ergogenic conditioning method used in sports science. Ingesting food during exercise for energy replenishment can cause gastrointestinal discomfort and stomach pain. However, CMR involves rinsing the mouth with a carbohydrate solution without ingestion, thus eliminating these concerns. Numerous previous studies in sports science have demonstrated the effectiveness of CMR in improving exercise performance,[21-24)] particularly during high-intensity intermittent exercise. CMR works by central fatigue inhibition rather than maximal strength enhancement, and has been proven effective for endurance activities. As an intervention mechanism, the effects of CMR on different brain regions (DLPFC, ventral striatum, anterior cingulate cortex [ACC], orbitofrontal cortex [OFC]) have been mediated centrally.[21)]

Recent research has focused on the activation of the DLPFC by CMR intervention during exercise and its impact on cognitive function. However, these previous studies applied moderate to high exercise intensity, while none used light-intensity exercise.

Since the effects of CMR on brain activity occur even without fatigue,[25)] we hypothesized that CMR intervention during LPA would synergistically lead to further improvement in executive function. Therefore, this study aimed to investigate the effects of CMR intervention during DE on executive function in young adults using short-duration LPA performed in a seated position, which is an activity easily accessible to anyone.

Materials and methods

Participants

The sample size was calculated using G*Power 3.1.9.4 (Institute for Digital Research and Education, Düsseldorf, Germany). Utilizing an F test for repeated measures with within-between interactions, an effect size of 0.25, a significance level of 5%, and a power of 80%, the a priori power analysis indicated that the required sample size was 12 participants per group.

The participants included 17 healthy university students (8 males and 9 females) who were recruited from July 23 to 30, 2021. Their physical characteristics are presented in Table 1.

(Table 1)

Block exercise

Block exercise (BE; "Co-kara"), Sakai City's version of dementia prevention exercises, was used for DE.[15] BE is a low-intensity exercise performed in a seated position, with an intensity of 2–3 METs.[26] BE consists of hand and leg movements (blocks) synchronized to music (Figure 1). The exercise allows for various movement patterns and rhythms, and can be performed to any preferred music, which helps maintain engagement and prevents boredom. One component of music is rhythm, and rhythmic activities, such as finger tapping, have been reported to activate brain regions including the DLPFC.[27-29] Based on this evidence, our study employed BE, an exercise synchronized with rhythm, to investigate its effects. In this study, heart rate was measured during BE, and exercise intensity was calculated using the Karvonen method[30]. The results showed a range of 3.9-21.2% HRmax, which was confirmed to meet the criteria for low-intensity exercise (<57% HRmax) as suggested by the ACSM [31].

(Figure 1)

Cognitive function task

Although various testing methods exist for evaluating cognitive function, we used the Japanese version of the New Stroop Test II (ST) and the Trail Making Test Type B (TMT-B), commonly used to measure executive function.

The ST evaluates an individual's ability to suppress interference from two pieces of information—letter meaning and letter color—and to make an attentional choice. The interference includes Stroop interference (SI), which eliminates letter meaning and reads letter color, and reverse-Stroop interference (RI), which eliminates letter color and reads letter meaning.

The New ST-II [32] consists of four tasks: reverse Stroop control condition, reverse SI condition, Stroop control condition, and SI condition. The control condition matches letter color and meaning, and the interference condition mismatches letter color and meaning. Each task consists of 10 practice tasks and 100 main tasks. The main task is performed for one minute. The interference rate is calculated from the results, which confirm the Stroop effect that occurs in Tasks 2 and 4 (SI conditions: incongruent) compared to Tasks 1 and 3 (control conditions: congruent). The formula for calculating the interference rate is shown below (Figure 2-B).

RI rate (Interference Rate I):

[(number of correct answers for Task 1 - number of correct answers for Task 2)/ number of correct answers for Task 1] x 100

SI rate (Interference Rate II):

[(number of correct answers for Task 3 - number of correct answers for Task 4)/

number of correct answers for Task 3] x 100

The TMT consists of two types of tests: TMT-A and TMT-B. TMT-A tests an individual's ability to connect numbers from 1 to 25 in sequence and mainly requires visual perception ability. The TMT-B primarily assesses working memory but also assesses task-set switching ability[33)] (Figure 2-A). The Japanese version of the TMT-B was used in this study.

Participants performed the cognitive function test on a Microsoft Surface Go 3 tablet by touching the screen. In addition, the participants practiced the TMT-B and ST several times beforehand.

(Figure 2)

Experimental protocol

The experiment was conducted simultaneously for each participant, and each trial was separated by an interval of at least three days. The participants were instructed not to engage in strenuous exercise or drink alcohol on the day before the experiment and not to consume anything other than water four hours before the start of the experiment. Once they arrived at the laboratory on the day of the experiment, the participants were instructed to rest in a seated position for 30 minutes in the center of a space surrounded by partitions on all four sides. They were asked to maintain a comfortable posture against the backrest of the chair until the end of the experiment. Heart rate was also measured using a polygraph system (RMT-1000, Nihon Kohden) and LabChart pro software (LabChart 8, ADInstruments) to evaluate exercise intensity.

The experiment consisted of four trials: Trial 1 [control (CON)], Trial 2 (CON+CMR), Trial 3 (DE), and Trial 4 (DE+CMR). The CON and CON+CMR procedures consisted of resting (five minutes) followed by performing three (TMT-B) tests and four different STs (see Figure 3). While in the sedentary posture, the participants then listened quietly to three music pieces, each about four minutes long. They rested for two minutes and completed the same cognitive function tests. DE and DE+CMR followed the same protocol as CON, but DE was performed with participants watching a recorded video during the experiment. Three songs (approximately 12 minutes in total) were chosen as the exercise duration because previous studies have reported that 11 to 20 minutes of exercise improves cognitive function regardless of the exercise intensity.[34] A medium speed tempo (moderato) was selected for the three songs: 92, 101, and 106 beats per minute, respectively.

We conducted a crossover randomized controlled experiment (1-2-3-4, 2-3-4-1, 3-4-1-2, 4-1-2-3) with four trials divided into four groups of participants. A sufficient number of test trials were conducted before the experiment to familiarize the participants with the experimental procedures, cognitive functions, and DE.

(Figure 3)

Carbohydrate mouth rinse

Although the carbohydrate solution was placed in the mouth and spat out in previous CMR studies, recent studies have proven that the spray method is equally effective.[24] A 6% concentration carbohydrate solution was used in this study based on previous research.[35] The CMR solution, which consisted of 30 g of glucose (manufactured by FUJIFILM Wako Pure Chemical Corporation) dissolved in 500 ml of water, was placed in a spray container (13 ml). The point of CMR implementation was indicated by arrows in Trials 2 and 4 (Figure 3). The participants were instructed to administer six pumps of solution into their mouth using the spray container, and not to swallow (Figure 4).

(Figure 4)

Analytic methods

The TMT-B was conducted three times each in both the pre- and post-treatment tasks. To reduce measurement error, the intraclass correlation coefficient (3,1) was used to detect the reliability of the three trials and the top two trials. Although reliability was over 0.5 in the top two trials, reliability over 0.4 was not detected in all three trials; therefore, the average of the top two scores was used for analysis (0.4 slight, 0.41–0.6 fair, 0.61–0.8 moderate, 0.81–1.00 almost perfect). The ST was analyzed using Interference Rates I and II.

The TMT-B performance time and ST Interference Rates I and II for each trial were compared by calculating the amount of change between the pre- and post-intervention results.

Statistical processing

SPSS Statistics 27 (IBM Corp., Armonk, NY, USA) was used for statistical processing. The data collected were verified for normality using the Shapiro–Wilk test and presented as mean ± standard deviation. Comparisons between trials were conducted using a two-way repeated measures ANOVA (Trial × Time). When interaction or main effects were observed, simple main effect tests and multiple comparison tests were used for further analysis. Effect sizes for ANOVA were analyzed using eta squared values (0.01 < small, 0.06 < medium, 0.14 < large). Bonferroni correction was applied for multiple comparisons while for outcomes where the ANOVA did not reveal a significant interaction effect, exploratory paired t-tests were conducted to examine pre-post differences within each condition. Effect sizes were analyzed using Cohen’s d values (0.2 < small, 0.5 < medium, 0.8 < large). Statistical significance was set at a 5% significance level.

Ethical considerations

The participants were fully informed of the study's purpose and methods. Once they understood these aspects, we obtained their written and verbal consent to participate in the experiment voluntarily. This study was conducted with the approval of the Ethics Committee of the Faculty of Health and Well-being, Kansai University (Ethics Review Number: 2021-08) and registered at the University Hospital Medical Information Network Center (UMIN Center) (UMIN Study No.: UMIN000054101).

Results

(Table 2) (Table 3)

Cognitive function tests were conducted using ST and TMT-B. A two-way repeated measures ANOVA (Trial × Time) for Interference Rate I in ST revealed an interaction effect ($F = 4.719$, $p = 0.006$, $\eta^2 = 0.228$). Additionally, main effects were found for both Trial ($F = 6.739$, $p = 0.001$, $\eta^2 = 0.296$) and Time ($F = 5.267$, $p = 0.036$, $\eta^2 = 0.248$). Subsequent post hoc analysis, including calculation of pre- and post-Interference Rate I changes and multiple comparisons, revealed significant differences between CON and DE ($p = 0.027$) as well as between CON and DE+CMR ($p = 0.024$) (Table 2). Paired t-tests of pre- and post-performance revealed significant cognitive improvements in both DE ($t\ [16] = 2.296$, $p = 0.036$, $d = 0.557$) and DE+CMR ($t\ [16] = 3.171$, $p = 0.006$, $d = 0.769$) trials (Table 3).

For Interference Rate II, the two-way repeated measures ANOVA (Trial × Time) also showed an interaction effect ($F = 4.246$, $p = 0.010$, $\eta^2 = 0.210$). While no main effect was found for Trial ($F = 1.977$, $p = 0.130$, $\eta^2 = 0.110$), a main effect was observed for Time ($F = 8.929$, $p = 0.009$, $\eta^2 = 0.358$). Post hoc analysis on changes in pre- and post-Interference

Rate II values and multiple comparisons indicated a significant difference between CON and DE+CMR ($p = 0.041$) (Table 2). Paired t-tests of pre- and post-performance established significant cognitive improvements in both DE ($t [16] = 2.413$, $p = 0.028$, $d = 0.585$) and DE+CMR ($t [16] = 5.135$, $p < 0.001$, $d = 1.245$) trials (Table 3).

For TMT performance, a two-way repeated measures ANOVA (Trial × Time) showed no interaction effect ($F = 2.249$, $p = 0.095$, $\eta^2 = 0.123$) (Table 2); a main effect for Time was observed ($F = 13.865$, $p = 0.002$, $\eta^2 = 0.464$). Exploratory paired t-tests revealed a significant difference between pre- and post-performance in the DE+CMR trial ($t [16] = 4.961$, $p < 0.001$, $d = 1.189$) (Table 3).

Discussion

We aimed to clarify the impact of combining DE, a seated form of LPA that is easy for anyone to engage in, with CMR on executive function in young adults.

The results showed that DE alone improved executive function, and the addition of CMR during DE suggested the potential for further enhancement in executive function.

Effects of DE

The effects of acute PA interventions on cognitive function improvement have been reported in numerous studies employing various types and intensities of exercise conditions. The mechanisms underlying these effects include the activation of the DLPFC, increased cerebral blood flow, and the secretion of neurotransmitters, such as catecholamines[36,37] and brain-derived neurotrophic factor (BDNF).[37] Prior research using functional near-infrared spectroscopy has reported enhancements in both DLPFC activation and cognitive functions following PA interventions.[3,4,6] In a previous study, the activation of the DLPFC during DE was measured using near-infrared spectroscopy, and this activation was also reported.[15] This brain activation is likely due to increased metabolic activity in the brain regions stimulated by exercise, which has been shown to positively impact cognitive functions.[38)]

Inhibition, an executive function necessary for performing the ST, has been shown to improve with physical activity (PA) in young adults.[39)] This suggests that the improvement in ST performance observed in this study can be attributed to this effect. The ST employed in this study activates brain regions such as the DLPFC, SMA, and PL during tasks associated with Interference Rate I. Conversely, the task characteristics for Interference Rate II primarily report DLPFC activation.[32)] In the multiple comparisons of the ST, significant improvements were found between the CON and DE groups for Interference Rate I ($p < 0.027$), while no significant improvement was observed for Interference Rate II (Table 2). This may be due to differences in task characteristics. The overlapping activation of brain regions, including the DLPFC, SMA, and PL, during Interference Rate I,[32)] suggests a strong influence of exercise on these areas.[3,4,8)] However, since only the DLPFC is primarily activated during the tasks associated with Interference Rate II,[32)] it is inferred that there were fewer regions activated by exercise compared to Interference Rate I.

Working memory, which is a necessary executive function for performing the TMT-B, has been shown to improve in young adults through PA.[39)] However, the results obtained from TMT-B in this study did not show significant interaction effects and main effects of trial conditions. This lack of significant findings may be due to the favorable results of TMT-B. Previous studies have reported that changes in cognitive function due to PA interventions are less likely to manifest when the pre-test scores are already high.[40)] In this study, the participants' pre-test scores were already higher than the typical TMT-B scores for their age group,[41)] which likely explains the absence of significant cognitive improvements between trials. This high performance may be attributed to the fact that participants underwent sufficient test trials before the experiment to familiarize themselves with the procedures and cognitive assessments. On the other hand, the intervention effect on TMT could not be confirmed from the results of the current experiment, but the main effect of time was significant, and the effect size in the DE+CMR condition was larger than in the other conditions, thus suggesting the possibility of a synergistic effect (Table 3).

DE has been reported to be effective in improving cognitive function.[18,19,42,43] However, to date, most studies on DE have included cognitive tasks during biking or walking. Therefore, the present study is significant as it reveals the effects of DE combined with music on improving cognitive function.

Effects of CMR

The brain is activated by CMR when the taste buds sense carbohydrates, and information is transmitted through the ACC to the DLPFC and OFC, which activate these areas.[44] CMR alone did not lead to brain activity indicating improved cognitive function, and no effect on improvement in cognitive function was observed.[45] This was consistent with the results of the CON+CMR trial in this study. In previous studies that implemented a CMR intervention during moderate to high intensity or prolonged exercise, improvement in cognitive function and suppression of decline were demonstrated.[46,47] However, as no studies have previously examined the effects of a CMR intervention during short-duration LPA, this study investigated the topic using DE.

As a result, in the multiple comparisons of the ST, significant differences were observed between the CON and DE groups, as well as between the CON and DE+CMR groups, for Interference Rate I. However, no significant difference was found between

DE and DE+CMR, indicating that the effects of exercise were strong enough to obscure the distinction of CMR's impact. By contrast, for Interference Rate II, no significant improvement was noted between the CON and DE groups, but a significant improvement was observed between the CON and DE+CMR groups ($p < 0.041$) (Table 2). This suggests that the addition of CMR to DE may have led to higher activation in brain regions, such as the DLPFC, ACC, and OFC, which are activated during the ST[32)] and by CMR.[21,32)] Particularly, the ACC showed strong activation during tasks involving interference[48)]; the activation of the ACC and DLPFC due to CMR may be significantly pronounced during the ST.

Additionally, no improvement in executive function was observed with either CMR or DE alone in the TMT-B. However, the effect size of the DE+CMR condition was greater than that of the other conditions, suggesting the possibility of a synergistic effect using DE and CMR (Table 3). This improvement may be attributed to the priming effect of CMR.[49)] The priming effect refers to how preceding stimuli can facilitate or inhibit subsequent stimuli. This study hypothesized that the preceding stimulus, DE, enhanced the effects of the subsequent stimulus, CMR.

Based on these findings, it is suggested that combining CMR with low-intensity, short-duration DE may lead to further improvements in executive function, without the necessity for moderate to high-intensity or prolonged exercise. However, this hypothesis remains speculative and requires validation based on physiological data, hence conducting further research to systematically examine these assumptions is crucial.

Limitations

This study has some limitations. The activation of the DLPFC was not directly measured, preventing a direct comparison with the mechanisms demonstrated in previous research. Therefore, further studies are needed to confirm the mechanisms suggesting the involvement of the DLPFC. Additionally, the absence of a CMR placebo solution trial is noted as another limitation, which should be considered in future research.

Perspective

The CMR used in this study can be applied in various educational settings and to improve the cognitive function of older adults and people with disabilities because this intervention is easily implemented during PA. In addition, DE performed in a seated position is easy for most people, and can be applied universally for those with disabilities or movement limitations. Future studies on CMR interventions during long-term PA and its effects on older adults are necessary.

Conclusions

The combination of short-duration DE and CMR in young adults suggests the potential for further improvements in executive function.

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Conflicts of interest

The authors declare no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Authors' contributions

All authors have made substantial contributions to the design of the study and the acquisition, analysis, and interpretation of the data. Donghyun KIM participated in drafting the manuscript and Tsuyoshi WADAZUMI revised it critically. All authors read and approved the final version of the manuscript.

Data availability statement

Data generated or analyzed during this study are provided in full within the published article.

Table 1. Participants' physical characteristics

		Age(year)	Height(cm)	Weight(kg)	BMI
Male(n=8)	Mean	21.1	173.6	66.1	22.0
	SD	0.4	4.3	8.1	3.5
Female(n=9)	Mean	21.1	160.4	51.9	20.1
	SD	0.3	4.1	5.4	2.0
Total(n=17)	Mean	21.1	166.6	58.6	21.0
	SD	0.3	7.9	9.8	2.9

Table 2. Results of analysis of variance for cognitive function tests

Cognitive Task	Trial	Pre		Post		Two-way RM ANOVA Trial × Time			Δ Post-Pre
		Mean	SD	Mean	SD	*F* value	*p* value	η_2	
TMT-B	CON	27.09	2.70	26.09	3.40	2.249	0.095	0.123	-1.00
	CON+CMR	26.50	3.29	25.81	3.26				-0.69
	DE	28.26	4.19	26.76	4.25				-1.50
	DE+CMR	26.84	3.12	24.03	1.96				-2.81
Stroop Interference Rate Ⅰ	CON	7.23	5.87	8.68	3.97	4.719	0.006**	0.228	1.5
	CON+CMR	3.96	2.95	2.87	3.72				-1.1
	DE	7.36	4.65	3.91	4.86				-3.5†
	DE+CMR	5.98	4.30	2.46	2.50				-3.5†
Stroop Interference Rate Ⅱ	CON	5.78	4.15	6.33	3.69	4.246	0.010**	0.210	0.6
	CON+CMR	3.04	5.72	2.74	6.10				-0.3
	DE	6.83	4.95	3.05	6.17				-3.8
	DE+CMR	6.41	4.05	2.26	3.21				-4.2†

Note. **p<0.01, ***p<0.001; Post hoc test (Bonferroni), †: vs. CON, †<0.05

Abbreviations: TMT-B, Trail making test type B; CON, Control trial; CMR, Carbohydrate mouth rinse; DE, Dual-task exercise.

Table 3. Results of t-test for cognitive function tests

Cognitive Task	Trial	*t*-test (Pre-Post)			
		t value	df	*p* value	Cohen's d
TMT-B	CON	1.565	16	0.137	0.380
	CON+CMR	1.258	16	0.226	0.305
	DE	1.704	16	0.108	0.413
	DE+CMR	4.961	16	0.001***	1.189
Stroop Interference Rate Ⅰ	CON	-1.413	16	0.177	-0.343
	CON+CMR	1.064	16	0.303	0.258
	DE	2.296	16	0.036*	0.557
	DE+CMR	3.171	16	0.006**	0.769
Stroop Interference Rate Ⅱ	CON	-0.476	16	0.640	-0.116
	CON+CMR	0.266	16	0.793	0.065
	DE	2.413	16	0.028*	0.585
	DE+CMR	5.135	16	0.001***	1.245

Note. *p<0.05, **p<0.01, ***p<0.001;

Abbreviations: TMT-B, Trail making test type B; CON, Control trial; CMR, Carbohydrate mouth rinse; DE, Dual-task exercise.

Figure captions

Figure 1. Motions performed during block exercise

Figure 2. Trail Making Test Type B, New Stroop test II

A: Trail Making Test Type B (TMT-B); B: New Stroop test II

Figure 3. Experiment protocol and cognitive task

TMT-B, Trail Making Test Type B; ST, New Stroop test II; CMR, Carbohydrate mouth rinse; DE, Dual-task exercise

Figure 4. Carbohydrate mouth rinse (spray method)

Figure 1

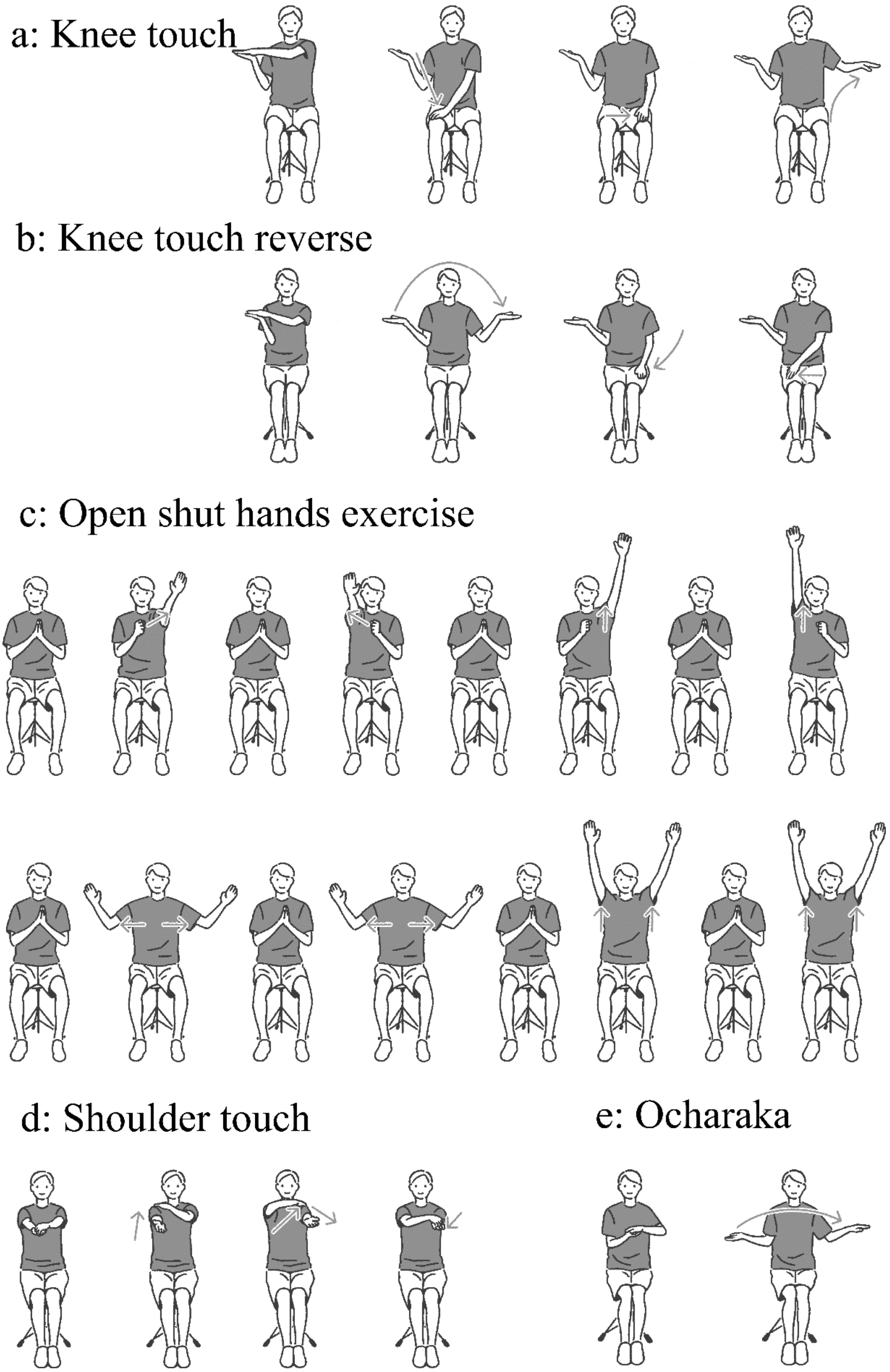
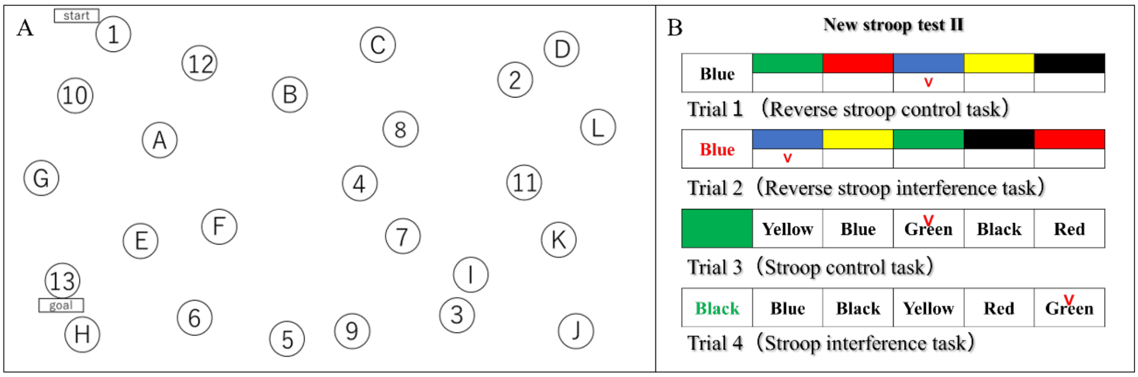
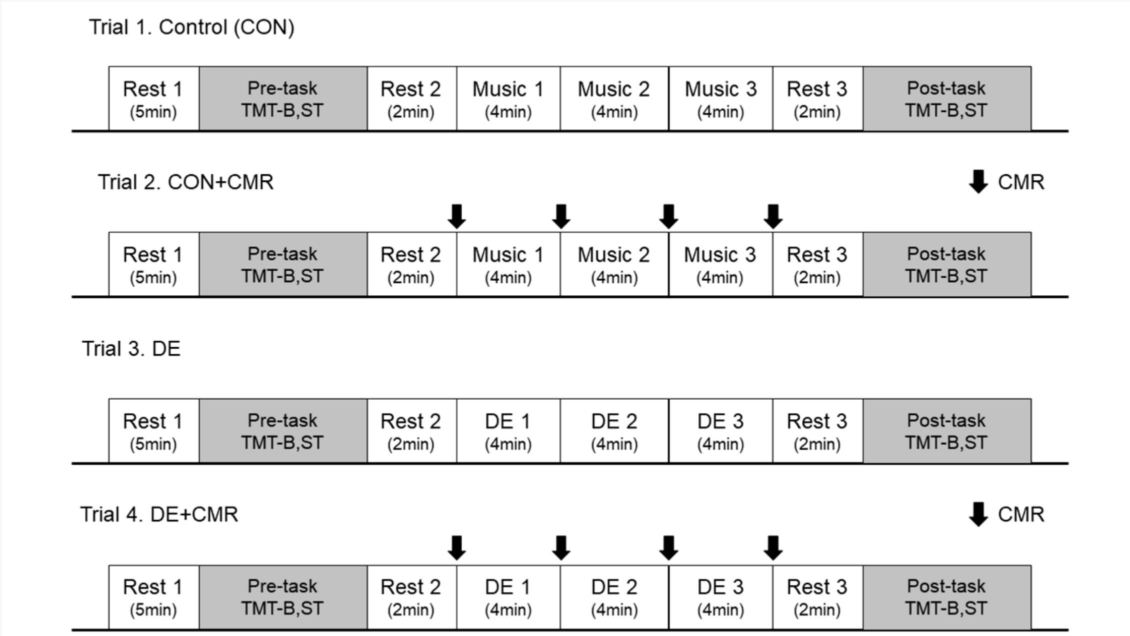

a: Knee touch
b: Knee touch reverse
c: Open shut hands exercise
d: Shoulder touch
e: Ocharaka

Figure 2



A
start
1
12
10
A
G
E
F
13
goal
H
6
5
9
3
B
C
8
4
7
2
D
L
11
K
I
J
B
New stroop test II
Blue
v
Trial 1 (Reverse stroop control task)
Blue
v
Trial 2 (Reverse stroop interference task)
Yellow
Blue
Green
Black
Red
Trial 3 (Stroop control task)
Black
Blue
Black
Yellow
Red
Green
Trial 4 (Stroop interference task)

Figure 3



Trial 1. Control (CON)
Rest 1 (5min)
Pre-task TMT-B,ST
Rest 2 (2min)
Music 1 (4min)
Music 2 (4min)
Music 3 (4min)
Rest 3 (2min)
Post-task TMT-B,ST
Trial 2. CON+CMR
CMR
Rest 1 (5min)
Pre-task TMT-B,ST
Rest 2 (2min)
Music 1 (4min)
Music 2 (4min)
Music 3 (4min)
Rest 3 (2min)
Post-task TMT-B,ST
Trial 3. DE
Rest 1 (5min)
Pre-task TMT-B,ST
Rest 2 (2min)
DE 1 (4min)
DE 2 (4min)
DE 3 (4min)
Rest 3 (2min)
Post-task TMT-B,ST
Trial 4. DE+CMR
CMR
Rest 1 (5min)
Pre-task TMT-B,ST
Rest 2 (2min)
DE 1 (4min)
DE 2 (4min)
DE 3 (4min)
Rest 3 (2min)
Post-task TMT-B,ST

Figure 4