

Impact of bilateral-coordinated movement on manipulative skill competency in school-aged children

Jun Chen

East China Normal University <https://orcid.org/0000-0003-4263-0759>

Xiaozan Wang

East China Normal University

Weiyun Chen (✉ chenwy@umich.edu)

University of Michigan <https://orcid.org/0000-0003-0380-0743>

Research article

Keywords: Manipulative skill competency; Midline crossing movements; Skill assessment

Posted Date: July 27th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-46038/v1>

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Abstract

Background Researchers found that manipulative skill competency in childhood not only help improve physical activity participation, but also help adolescent learn specialized sport skills. This study aimed at examining the effects of an 8-week bilateral-coordinated movement (BCM) intervention on manipulative skill competency in school-aged children.

Methods Participants were 314 fourth-grade students in two elementary schools. This study used 2-arm quasi-experimental research design. For one elementary school, two fourth-grade classes were assigned to the BCM group, the other two fourth-grade classes were assigned to the control group. For another elementary school, one fourth-grade class was assigned to the BCM group and another fourth-grade class to the control group. The students in the BCM group received an 8-week, two 40-minute BCM lessons in soccer and another 8-week, two 40-minute BCM lessons in basketball, while the control group received an 8-week, two 40-minute regular PE lessons in soccer and basketball, respectively. Students' manipulative skill competency in soccer and basketball skills were pre- and post-tested using the two PE Metric assessment rubrics. Data were analyzed by means of descriptive statistics, independent sample t test, ANCOVA and ANOVA repeated measures.

Results The results showed a significant main effect of time (pre-test vs. post-test) in soccer skills ($F = 273.095, p = .000, \eta^2 = .468$) and in basketball skills ($F = 74.619, p = .000, \eta^2 = .193$). Also, the results revealed a significant main effect of group (BCM group vs. control group) in soccer skills ($F = 37.532, p = .000, \eta^2 = .108$), marginal significant main effect of group in basketball skills ($F = 3.619, p = .058, \eta^2 = .011$). Further, there was significant interaction effect between the time and group in soccer skills ($F = 37.532, p = .000, \eta^2 = .108$) and in basketball skills ($F = 18.380, p = .000, \eta^2 = .056$).

Conclusions It was concluded that after participated in the 8-week, 16 40-min lessons of BCM, the fourth-grade students had greater improvement in soccer and basketball dribbling, passing and receiving skills, compared to the control group.

Background

Studies have evidenced that manipulative skill competency developed in childhood is an important contributor to their participation in physical activities during adolescence [1]. Manipulative skill competency is referred to the ability to perform skills that use hands, feet, other body parts, and objects to manipulate or control an object (e.g., dribbling with hands, overhand throwing a ball, striking a ball with the racket) with proper forms consistently and proficiently [2–5]. Developing manipulative skill competency in childhood is instrumental to school-aged children to be physically active, especially increasing physical activity participation in later life [1, 5–8]. Barnett et al. [1] found that children's motor skill proficiency, especially manipulative skill proficiency predicted adolescent physical activity. Thus, Barnett et al. [1] suggested that in the development of elementary school students' motor skill competency, more attention should be paid to improving manipulative skills than locomotor skills. Given

the fact that the majority of youth were insufficiently active [9], it is important to improve manipulative skill competency in childhood in order to increasing physical activity participation.

The goal of quality physical education (PE) is to develop physically educated individuals who have knowledge, skills, and confidence to enjoy a lifetime of physical activity [10]. In line with this, helping students develop manipulative skill competency is one of desired learning outcomes based on the National Physical Education Content Standard 1 [10]. Studies have shown that quality PE program can improve manipulative skill competency in school-aged children [11–13]. Mckenzie et al. [11] found that quality PE programs delivered by certified PE teachers and classroom teachers with extensive training can effectively improve children's manipulative skill. Chen et al. [12] found that the overall quality of PE teaching and four essential dimensions of quality PE teaching practices (i.e., task design, task presentation, class management, and instruction guidance) significantly contributed to developing students' manipulative skill competency. Robinson et al. [13] found that supportive instructional climates are beneficial to learning manipulative skills. In short, the development of children's manipulative skill competency is based on the interaction of environment and tasks [14].

Empirical studies have shown that bilateral-coordinated movements contributed to improved manipulative skill competency [15–17]. Coordinated-bilateral activities refer to the use of both hand or feet and more parts of the body to perform movements that cross the midline of the body [18, 19]. Manual midline crossing movements are involved in crossing the midline of the body and manipulating objects in the opposite space so that both hands can be practiced [20, 21]. Basketball dribbling is a typical skill crossing the body's midline. For example, crossover dribbling is performed from right to left, left to right. Cermak et. al. [22] found that children aged 8–9 years are the critical periods for developing their ability to cross the body midline. Incorporating midline crossing movements into sports may help children achieve greater motor skill performance [23]. For example, when a basketball player dribbles while changing directions in order to beat defense, he or she must be able to use both hands to dribble the ball. Similarly, when a soccer player breaks through a defender, he must be able to dribble with both dominant and non-dominant feet. In addition, the previous studies found that bilateral-coordinated movement practices were beneficial for children to improve dribbling and kicking skills in soccer performance [15], dribbling and shooting skills in basketball [16, 17], and a throwing skill [21]. However, a few previous studies have focused on examining the effects of the bilateral-coordinated movement on improving children's manipulative skill competency.

To date, there is a few of study examining the effects of bilateral-coordinated movement (BCM) PE lessons on students' manipulative skill competency. Therefore, the purpose of this study was to examine the effects of the BCM intervention on manipulative skill competency in fourth-grade students who were assessed with selected PE Metrics assessment rubrics [24]. Our research hypothesis was that students in the BCM intervention group will show significantly greater increase in their manipulative skill competency assessed with the PE-Metric assessment rubrics compared to the control group. The significance of this study lies in providing empirical evidence for the BCM intervention improving students' manipulative skill competency during PE lessons.

Methods

Participants and research settings

Participants in this study were 314 fourth-grade students (boys = 182; girls = 132; Mean age = 9.7 years old) at two elementary schools during a school year of 2018–2019. A two-arm quasi-experimental designed was used in this study. For one elementary school, we assigned two fourth-grade classes to the BCM group and other two fourth-grade classes to the control group. For another elementary school, we allocated one fourth-grade class to the BCM group and another fourth-grade class to the control group. Each participating fourth-grade class regardless of conditions at each of the two elementary schools had three 40-min of PE lessons per week. The PE class size ranged from 48–55 students. The PE Teachers' ages varied from 27–47 years old with a range of 7–30 years of teaching experience. Each school's principal granted the permission for their school to participate in this study. The university Institutional Review Board (HUM00149529) approved the study protocols. The students' parent/guardian signed the consent form to allow their children to participate in this study. All four PE teachers signed the consent form to indicate their voluntary participation in this study.

Treatment

BCM group. The students in the BCM group received the 8-week, 16 40-minute BCM lessons in soccer and the 8-week, 16 40-minute BCM lessons in basketball during fall semester of 2018 and spring semester of 2019. To ensure each intervention PE teacher implement the key intervention content in each BCM lesson, we designed the structured 16 BCM soccer lesson plans for an 8-week unit and 16 BCM basketball lesson plans for an 8-week unit based on the school-scheduled length of PE lesson. Each structured BCM lesson plan consists of three key content components: (1) 5–8 minutes of bilateral-coordinated aerobic movements as warm-ups; (2) 15–20 minutes of sequential skill building tasks focusing on bilateral-coordinated motor skills including manipulative skills (i.e., dribbling, catching, passing, shooting) in combination with locomotor skills (i.e., running, jumping, skipping). The manipulative skills along with locomotor skills used in playing sports and aerobic activities are core PE contents aligned with the national PE content standards for grades 3–5 [10]. The students use bilateral, eye-hand and multi-limb coordination to engage the sequential skill building tasks; and (3) 8–10 minutes of skill-applying coordinated aerobic sport games tasks in which students apply skills in cognitively-challenging, dynamic, and changing environments (e.g., play a dribble tag game with groups of 4 within the designated playing area). At the end of each lesson, there are 3–5 min of lesson debriefing in which students will self-reflect on their skill and game performances. While the intervention PE teachers are required to teach the same curriculum content within the same lesson structure, they have flexibility to modify and adjust some of specific learning tasks and the organization of them as well as the pace of the task progression based on the class size, available facilities and equipment, and students' learning responses.

During the second to the last week of July, 2018, the corresponding investigator who designed the 16 BCM soccer lessons plans and the 16 BCM basketball lessons trained the PE teachers in learning and teaching sample BCM lessons in soccer and basketball during a 5-day BCM training (6 hours per day). Details in training were described elsewhere. During the fall semester, each trained PE teacher used the 16 BCM soccer lesson plans to teach 16 BCM soccer lessons (two 40-min lessons per week) to their students in the intervention classes for eight consecutive weeks. Similarly, during the spring semester, each trained PE teacher used 16 BCM basketball lesson plans to teach 16 BCM basketball lessons (two 40-min lessons per week) to their students in the intervention classes for eight consecutive weeks.

Control group. The students in the control group followed their school curricular schedules. During the fall semester of 2018, each control PE teacher used their lesson plans and usual teaching methods to teach 16 soccer lessons (two 40-min soccer lessons per week) to their students in the control classes for eight consecutive weeks. During the spring semester of 2019, each control PE teachers used their lesson plans and usual teaching methods to teach 16 basketball lessons (two 40-min basketball lessons per week) to their students in the control classes for eight consecutive weeks.

Motor Skill Assessments

Soccer dribbling, passing, and receiving skills. For the soccer skills assessment, the students' performances levels were assessed on the three essential dimensions: Dribbling, Passing, and Receiving with a 0–4 rating scale. One trial was allowed for the test. Criteria for Competence (level 3) for Dribbling is: "dribble with control while moving at a slow, consistent jog," for Passing is: "sends a receivable lead pass to a partner so it can be received outside the passing lane without a break in the receiver's stride on at least 3 passes," and for Receiving is: "moves forward and outside the passing lane to meet the ball while receiving at least 3 receivable passes". ([24], p. 120). A total score of 9 indicated an Overall Competent Level. The maximum score is 12.

Basketball dribbling, passing, and receiving skills. For the basketball skills assessment, the students' performances levels were assessed on the three essential dimensions: Dribbling, Passing, and Receiving with a 0–4 rating scale. One trial was allowed for the test. Criteria for Competence (level 3) for Dribbling is: "dribbles with control while moving at a slow, consistent jog," for Passing is: "sends a catchable lead pass to a partner so it can be caught outside the passing lane without a break in the receiver's stride on at least 3 passes," and for Receiving is: "moves forward and outside the passing lane to meet the ball while receiving at least 3 receivable passes". ([24], p. 98). A total score of 9 indicated an Overall Competent Level. The maximum score is 12.

Prior to the fall semester began, both intervention and control PE teachers were trained in learning the two PE Metrics assessment rubrics, assessment criteria, assessment tasks, and testing protocols for soccer and basketball skills, how to organize students to perform soccer skill and basketball skill assessment tasks. During the fall semester, at pre-test, the PE teachers organized the participating students to perform soccer dribbling, passing, and receiving skills in regular PE lessons during the last two weeks of

September. At the post-test, the PE teachers organized the students to perform the same skills in regular PE lessons during the second and third weeks of December. During the spring semester, the students were pre-tested in basketball dribbling, passing, and receiving skills during the first two weeks of March organized by the PE teachers. Again, the students were post-tested the same basketball skills as above during the last two weeks of May organized by the PE teachers. During the testing lessons, first, the PE teacher demonstrated and explained how to take the test based on the PE Metrics testing directions. Next, the PE teacher organized the students into each pair and gave each pair two practicing trials to ensure all students understand the testing procedures. Last, the PE teacher organized each pair to take the test which was video-recorded using the digital camera.

In this study, the Cronbach's alpha reliability coefficients of soccer skills, basketball skills assessments were 0.90, 0.82, respectively. The results showed that the two manipulative skill assessments had satisfactory internal consistency reliability [25].

Evaluation Of Students' Performance In Soccer And Basketball Skills

Prior to evaluating the students' performance in both soccer and basketball skills, four evaluators were trained in use of the PE Metrics assessment rubrics to assess each students' performance in soccer and basketball skills by the corresponding authors. Then, the four evaluators who were paired-up began to practice coding six 4th -grade students' performance in soccer and basketball skills, respectively which were video-recorded for the other study. Each pair practiced coding for about three hours while discussing questions with the correspondingly spontaneously and finalized the coding protocols. Next, each student in each pair independently coded the four students' performance in the soccer and basketball skills with the PE Metrics assessment sheet to check the inter-rater reliability (IR). The IR of the coded soccer or basketball skills assessments was examined by checking each evaluator's coding results using the formula: % IR = (number of agreement ÷ (numbers of agreement + numbers of disagreement)) × 100 [26]. Finally, when the IR of the three coded soccer or basketball skills was above 80%, four evaluators began to officially code all video-recorded students' performance in both soccer and basketball skills with the PE Metric assessment sheet using the coding protocols. The two evaluators in each pair watched the recorded video together, but each evaluator independently coded each video-recorded students' performance in both soccer and basketball skills. Each evaluator was required to strictly use the PE Metrics Assessment rubrics [24] to conduct the two manipulative skill assessments with all participating students.

Data analysis

SPSS statistics software (Version 26.0; IBM Cooperation, Armonk, NY, USA) was used to conduct all statistical analysis of the data. To determine levels and proportions of boys' and girls' demonstration of competency in two manipulative skill assessments, descriptive statistics and percentages were

computed. To examine the pre-test mean score differences in each skill assessment between the BCM and control groups, the independent sample *t* test was conducted. Independent *t*-test showed the pre-test significant difference in the mean score of overall competent level in soccer skills between the two groups ($t=7.013, p = .000$). To examine the intervention effects on the overall soccer skill competency, a 2×2 mixed-design analysis of covariance (ANCOVA) with repeated measures was conducted. In the ANCOVA repeated measure analysis, time (pre-test vs. post-test) was treated as a within-subject factor and treatment condition (BCM group vs. control group) was treated as a between-subject factor, the pre-test in soccer was a covariate to control for baseline differences.

Due to no pre-test significant difference in the overall competent level in basketball skills between the two groups ($t=-1.021, p = .308$), ANOVA repeated measure was conducted with the time (pre-test vs. post-test) as a within subject factor and group (BCM group vs. control group) as a between-subject factor to examine if there was a significant intervention effect on basketball skill competency between the two groups. An alpha level of .05 was set for all statistical analysis.

Results

Soccer skill assessments

Table 1 presents the descriptive statistics of pre-test and post-test in soccer skill assessment between the two groups and by gender. For the soccer dribbling, passing, and receiving skill assessment, a total score of 9 indicated the Overall Competent Level. As seen in Table 1, at the pre-test, 23% of 90 boys and 25% of 69 girls in the BCM group demonstrated the Competent Level or above in soccer skills. In contrast, 68% of 92 boys and 55% of 62 girls in the control group demonstrated the Competent Level or above in soccer skills. At the post-test, 49% of boys and 62% of girls in the BCM group demonstrated the Competent Level or above in soccer skills. Conversely, 51% of boys and 37% of the girls in the control group demonstrated the Competent Level or above in soccer skills.

Table 1
Manipulative skill assessment performance of the students in the two cohorts

BCM		Control		
	M (SD)	# of OCL (% of OCL)	M (SD)	# of OCL (% of OCL)
Soccer (competence score: 9)				
Pre-test				
Boys (n = 90)	5.78 (3.90)	21 (23%)	9.14 (2.50)	63 (68%)
Girls (n = 69)	6.07 (3.42)	19 (25%)	7.65 (3.26)	34 (55%)
Total (n = 159)	5.91 (3.69)	40 (25%)	8.54 (2.92)	97 (63%)
Post-test				
Boys (n = 92)	8.13 (3.14)	44 (49%)	8.30 (2.52)	46 (51%)
Girls (n = 62)	8.65 (2.40)	43 (62%)	7.60 (2.27)	23 (37%)
Total (n = 154)	8.36 (2.84)	87 (55%)	8.02 (2.43)	69 (45%)
Basketball (competence score: 9)				
Pre-test				
Boys (n = 89)	5.65 (2.17)	5 (6%)	5.39 (2.33)	4 (4%)
Girls (n = 69)	3.75 (2.44)	2 (3%)	4.67 (2.11)	2 (3%)
Total (n = 158)	4.82 (2.47)	7 (4%)	5.10 (2.26)	6 (4%)
Post-test				
Boys (n = 93)	7.96 (2.86)	41 (46%)	6.23 (2.17)	13 (14%)
Girls (n = 63)	5.80 (3.14)	12 (17%)	5.25 (2.50)	6 (10%)
Total (n = 156)	7.01 (3.16)	53 (34%)	5.83 (2.35)	19 (12%)

As presented in Table 2, the results of ANCOVA repeated measure showed a significant main effect of time ($F= 273.095, p= .000, \eta^2 = .468$), a significant main effect of group ($F= 37.532, p= .000, \eta^2 = .108$), and a significant interaction between the time and group ($F= 37.532, p= .000, \eta^2 = .108$) in the overall soccer competency score. The results indicated that when the pre-test scores of the two groups were controlled, the BCM group showed significant improvement in the overall soccer skills competency from pre-test to post-test, while the control group reduced the overall soccer skill competency over times.

Table 2
Results of the repeated measure ANCOVA and ANOVA for manipulative skills between the two cohorts

Dependent Variables	Factors	F	df	P	η^2
Soccer	Time	273.095	1	.000	.468
	group	37.532	1	.000	.108
	Time*Group	37.532	1	.000	.108
Basketball	Time	74.619	1	.000	.193
	group	3.619	1	.058	.011
	Time*Group	18.380	1	.000	.056

Basketball Skill Assessments

Table 1 presents the descriptive statistics of pre- and post-test in basketball skill assessment between the two groups and by gender. For the basketball dribbling, passing, and receiving skill assessment, a total score of 9 indicated the Overall Competent Level. At the pre-test, 6% of 89 boys and 3% of 69 girls in the BCM group demonstrated the Competent Level or above in basketball skills. Similarly, 4% of 93 boys and 3% of 63 girls in the control group demonstrated the Competent Level or above in basketball skills. However, at the post-test, 46% of boys and 17% of girls in the BCM group demonstrated the Competent Level or above in basketball skills, while 14% of boys and 10% of girls in the control group demonstrated the Competent Level or above in basketball skills.

As presented in Table 2, the results of ANOVA repeated measure revealed a significant main effect of time ($F = 74.619, p = .000, \eta^2 = .193$), marginal significant effect of group ($F = 3.619, p = .058, \eta^2 = .011$), and a significant interaction between time and group ($F = 18.380, p = .000, \eta^2 = .056$). The BCM group showed significant increase in the basketball skills competency from pre-test to post-test, compare to the control group. The results revealed a significant intervention effect in improving the basketball skill competency.

Discussion

This study was central to examining the effects of the BCM interventions on manipulative skill competency in soccer and basketball skills among school-aged children. After the 8-week intervention, the students in the BCM group demonstrated significant improvement in the two manipulative skills over time, compared to their counterparts in the control group. In addition, in the BCM group, 55% of students demonstrated a competent level or above in the soccer skills and 34% of students demonstrated a competent level or above in the basketball skills at the post-test. Our result confirmed that BCM in PE lessons can improved students' manipulative skill competency.

Consistent with the results in the present study, previous studies have shown that bilateral-coordinated practice improved manipulative skill in school-aged children [15–17]. Teixeira et al. [15] found that adolescents' participating in five, two-hour bilateral practice lessons per week over the course of four months helped reduce the lateral asymmetries of performance assessed on three soccer skills: kicking for force, kicking for accuracy, and speed of dribbling. Teixeira et al. [15] suggests that spending more time in non-dominant limbs is conducive to achieving good motor skill performance. Further, Stöckel et al. [16] found that sixth- and seventh-grade students, who participated in eight, 45-minute bilateral practice of hand dribbling skills over four weeks, showed significant improvement in basketball dribbling skills, compared to the comparison students. In addition, Pedersen [23] found that specific midline crossing coordinated activities improved children' processing speed of lateral movements.

The finding of this study indicated that students, who participated in the bilateral-coordinated movement throughout the 16 lessons, significantly improved their overall skill competency in both soccer and basketball skills. In order to improve the students' manipulative skill, we designed soccer and basketball lesson plans including three key components: bilateral-coordinated aerobic movements (warm-ups), building tasks focusing on bilateral-coordinated manipulative skills in combination with locomotor skills, skill-applying coordinated aerobic sport games tasks. Development of motor skill is dependent on the organismic interactions with task and environment [27].

Dribbling, passing and receiving skills in soccer and basketball are basic specialized sport skills often used in playing soccer and basketball games. Most importantly, mastering these basic specialized skills during childhood would be beneficial to their later motor skills learning. The fundamental movement skills are associated with organized physical activity in adolescents [6]. Due to the trend of decreasing physical activity participation in youth [9], it is important to improve children's manipulative skill competency. This study suggests that to better equip children with manipulative skill competency in sport-related skills, PE teachers should devote their instructions to the bilateral-coordinated movement practice in basic specialized skills, For example, in this study, in order to improve basketball dribbling skill, we have designed a variety of dribbling activities (e.g., dribble while walking, crossover dribble while walking, dribble while running, dribble on zigzag pathways, dribble at different speeds et al.) combined with bilateral-coordinated practices such as dribble while walking or running on a straight pathway with different hands, dribble with walking or running on curved pathways while changing direction and hands.

It is important to note several implications associated with the findings of this study. First, this is the first study has attempted to examine the effects of BCM on manipulative skill competency in elementary school students who were assessed with selected PE Metric assessment rubrics. The results of this study show that students significantly improved their manipulative skill competency through participating in structured BCM lessons. Second, this study adds to literature on manipulative skill assessment with the PE Metrics assessment rubrics. This study suggests that the PE Metrics assessments are useful tools for measuring students' manipulative skill competency in future studies. Third, given the promising results of the BCM in this study, future studies may consider designing BCM intervention studies to improve other

manipulative skill competency such as striking skills, throwing skills, passing skills, and catching skills among school-aged children.

The limitation of the study was that this study used the quasi-experimental design. The BCM group and the control group were allocated based on the choice of the PE teachers. Given that, the study can't control for the baseline differences in the overall competency score in soccer skills between the two groups, with the control group having a significantly higher score. In addition, this study was limited to the use of BCM as the intervention strategies to improve manipulative skill competency in soccer and basketball skills. The future study could examine BCM on other manipulative skill competency (e.g. overhand throwing, striking with a paddle) and locomotor skill competency (e.g. jumping, dance) in school-aged children.

Conclusions

The students, who participated in the two 8-week, 16 40-min BCM lessons, showed significant improvements in soccer and basketball dribbling, passing, and receiving skills, compared to the control group. This study suggests that engaging students in BCM is an effective strategy to improve manipulative skill competency in school-aged children.

Abbreviations

BCM: bilateral-coordinated movement; PE:physical education

Declarations

Availability of data and materials

Based on the consent form indicating that the data will not be shared publicly for confidentiality, we will not share our data with the public.

Competing interests

There is no conflict of interests regarding financial and /or no-financial aspects. We do not have any financial interests of the subject matter discussed in the manuscript.

Consent for publication

Yes

Ethics approval and consent to participate

This project approved by the Institutional Review Board-Health Sciences and Behavioral Sciences at the University of Michigan (HUM00149529). Shengli Road elementary school and Luoyang experimental

elementary school granted the permission for conducting this study as well. The parent/guardian signed the consent form for allowing their child's participation in this project. The students were given the assent form for their approval of participation in this project.

Note

BCM = bilateral-coordinated movement, OCL = Overall Competent Level

Funding

This study was funded by National Social Science Foundation of China (Project ID: 16ZDA228).

Authors' contributions

JC searched the literature on bilateral-coordinated and manipulative skill, contributed to data collection and analysis, wrote the manuscript. XW participated in the design of the study and contributed to data collection. WC designed the project, contributed to data collection and data analysis, wrote and edited the manuscript. All authors have read and approved the final version of the manuscript, and agreed with the order of the presentation of the authors.

Acknowledgments

We are thankful for the students and their physical education teachers at Shengli Road elementary school and Luoyang experimental elementary school to participate in this project. The authors thank the following students for their assistance and contribution to evaluating the students' soccer and basketball skills using the PE Metrics Rubrics and to inputting the assessed data: Shijun Wu, Shirui Hou, Minmin Chen: Students of the College of Physical Education and Health, East China Normal University. Yanli Hao: Ph.D. student of the College of Physical Education and Health, East China Normal University. She translated 16 structured soccer lesson plans for 8-week soccer unit and 16 structured basketball lesson plans for 8-week basketball unit from English into Chinese. Zhanjia Zhang: Ph.D. student of the School of Kinesiology, University of Michigan. His advice on data analysis and review of manuscript.

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