CHANGES IN UPPER LIMB COORDINATION AND KINEMATICS FOLLOWING A FIVE WEEK INSTRUCTIONAL UNIT IN CUP STACKING

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Abstract

Cup stacking is a sport played in over 6600 physical education and after school programs in the United States. The leading manufacturer, Speed Stacks, Inc., claims that cup stacking promotes hand-eye coordination, ambidexterity, quickness, concentration, and bilateral proficiency. Since the sport is still fairly new, there have only been a few scientific studies on the influence of cup stacking (Conn, 2003; Hart, Smith, & DeChant, 2003; Udermann, Murray, Mayer, & Sagendorf, 2003) on psychomotor parameters.

The purpose of this study was to measure upper limb coordination changes using a five week cup stacking intervention. The specific aims of this study were to measure upper limb coordination changes with a star tracer task and two subtests of the Burininks-Oseretsky Test of Motor Proficiency, as well as to three dimensionally analyze the sport of cup stacking. We used the Peak Performance Motion Analysis System (Motus Ver. 7.3.2, Centennial, CO.) to measure cup clearance height and time to up stack.

A one-way MANCOVA was used to analyze the results. The independent variable for this study was cup stacking instruction. The dependent variables for this study were the post-test star tracer times, post-test star tracer errors, post-test bilateral coordination scores, post-test upper limb coordination scores, post-test up stack times, and post-test cup clearance heights. All pre-test scores were used as a covariate to investigate differences between groups in the post-tests Significance differences were evaluated with alpha set at 0.05.

Two of the variables investigated showed significance. The groups were significantly different (*Lambda*(6,12) = .749, $F = 5.98$, $p < .005$) in the star tracer

post-test times when the star tracer pre-test times were used as a covariate. The groups were also significantly different (*Lambda*(6,12) = .359, $F = 3.57$, $p < .05$) in the time to up stack when the upper limb coordination scores were used as a covariate. The star tracer error, bilateral coordination subtest, upper limb subtest, cup clearance height, and time to up stack showed no significance between groups in the post-test when the pre-tests were used as a covariate.

We found that cup stacking has a positive effect on the development of bilateral coordination in sixth grade physical education students. This is a very powerful statement, as the development of bilateral coordination is a variable that everyone does throughout their life. From birth everyone is constantly developing coordination patterns that occur on both sides of the body. Bilateral coordination is a variable that is used in everyday activities as well as sporting activities. The results of this study suggest that cup stacking can lead to better development of bilateral coordination.

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CHAPTER ONE

Introduction

Physical educators are constantly searching for new and innovative activities to include in their programs. Many of these activities are non-sport specific, but encourage a student's understanding of movement concepts. One of these activities is cup stacking. This activity has become so popular that competitions and associations have been formed, transitioning cup stacking from an activity to a sport. Cup stacking in now taught in over 6600 physical education and after school programs throughout the United States.

The National Association for Sport and Physical Education (NASPE) has identified seven content standards for physical education. The first standard on their list states that a physically educated person "Demonstrates competency in many movement forms and proficiency in a few movement forms" (NASPE, 1995, p. 2). Movement competency has been defined by NASPE (1995) as "the development of sufficient ability to enjoy participation in physical activities and establishes a foundation to facilitate continued motor skill acquisition and increased ability to engage in appropriate motor patterns in daily physical activities" (NASPE, 1995, p.2). While it is the physical educator's responsibility to teach students how to demonstrate movement competency, assessment methods for movement competency are varied. Reaction time, hand-eye coordination, bimanual, and bilateral coordination patterns have all been scientifically quantified in order to measure an aspect of movement competency. Specifically, bimanual movements have been studied in recent years in order to understand how one side of the body moves in relation to the other side.

Areas that have been studied include timing of bimanual coordination in discrete and continuous tasks (Semjen, 2002), age-related differences on the role of augmented visual feedback in learning a bimanual coordination pattern (Wishart, Lee, Cunningham, & Murdoch, 2002), and how the learning of a new bimanual coordination pattern is influenced by existing attractors (Wenderoth, Bock, & Krohn, 2002). The complexity of learning a new bimanual task has also been investigated. Studies using the dynamic systems theory (Monno, Temprado, Zanone & Laurent, 2002; Robertson, 2001; Smethurst & Carson, 2001;) and both electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) (Dabaere, Swinnen, Beatse, Sunaert; Gerloff & Andres, 2002; Van Heck, & Duysens, 2001) brain analyses have attempted to quantify how change occurs in learning a new bimanual task. All of these studies concluded that learning a bimanual task is complicated and affected by many factors. Since these studies suggest that the learning of bimanual skills is very complex, how does this impact how physical education teachers teach it in their classrooms?

In recent years, a new sport called cup stacking has emerged in physical education. It first began as an activity in boys and girls clubs 20 years ago and has now evolved into a nationwide sport in the United States. The governing organization, the World Cup Stacking Association (WCSA), oversees all rule regulations and competitions. State competitions have been held in Colorado, Texas, Florida, California, Missouri, and Georgia. Speed Stacks, Inc. is a leading manufacturer in the special cups used in the sport of cup stacking. The company claims that cup stacking promotes hand-eye coordination, ambidexterity, quickness, concentration, and bilateral proficiency. It also states that these measures of movement proficiency can help in activities such as dribbling a basketball, catching and throwing a baseball, playing a musical instrument, and typing on a computer.

If these claims were scientifically supported, it would indicate that cup stacking can lead to movement proficiency and coordination of bimanual movements. Since the sport is still fairly new, there have only been a few scientific studies on the influence of cup stacking (Conn, 2003; Hart, Smith, & DeChant, 2003; Udermann, Murray, Mayer, & Sagendorf, 2003). Udermann et al. (2003) assessed the influence of cup stacking on hand-eye coordination and reaction time of second grade students. They used a five week cup stacking unit in which the participants performed cup stacking exercises during their physical education class. The researchers found significant improvements in hand-eye coordination and reaction time in the experimental group. Conn (2003) assessed the effect of cup stacking on reaction time and movement time in fourth grade students. She investigated cup stacking exercises in conjunction with the student's regular physical education activities. She found a significant difference in movement time for both the experimental group and control group, but not in reaction time for either group. These studies suggest that cup stacking may have a legitimate scientific basis behind the manufacturer's claims.

Hart, Smith, & DeChant (2003) investigated the effect of cup stacking on hand-eye coordination in first, third and fourth grade students, and found no significant differences in two of three measures of hand-eye coordination. They suggested that three weeks of cup stacking isn't enough time to elicit changes in hand-eye coordination. They suggested further research be done on the effect of cup stacking.

Statement of the Problem

While some scientific evidence exists about the benefits of cup stacking, no studies have attempted to assess cup stacking as a means of changing bilateral coordination patterns. Furthermore, more scientific evidence is needed to measure the validity of a cup stacking program in a physical education curriculum. The leading manufacturer in the sport of cup stacking, Speed Stacks, Inc., claims that cup stacking promotes bilateral coordination. Cup stacking is widely used in physical education programs on the belief that it does help increase upper limb coordination. Some evidence exists on the proper duration of a cup stacking unit (Udermann et al, 2003), but others (Hart, Smith, & DeChant, 2003) suggest that three weeks is not enough time to make hand-eye coordination changes. More research needs to be undertaken to study the benefits, or lack thereof, of cup stacking.

Purpose of the Study

The purpose of this study was to measure upper limb coordination changes using a five week cup stacking intervention. The specific aims of this study were to measure upper limb coordination changes with a star tracer task and two subtests of the Burininks-Oseretsky Test of Motor Proficiency, as well as to three dimensionally analyze the sport of cup stacking. We used the Peak Performance Motion Analysis System (Motus Ver. 7.3.2, Centennial, CO.) to measure cup clearance height and time to up stack.

Hypotheses

- A significant decrease in time for the cup stacking group will be observed in the star tracer task when comparing the pre-test to the post-test
- A significant decrease in errors for the cup stacking group will be observed in the star tracer task when comparing the pre-test to the post-test
- A significant increase in the score of the bilateral coordination subtest of the Bruininks-Oseretsky Test of Motor Proficiency-Long Form (BOTMP-LF) in the cup stacking group will be observed when comparing the pre-test to the post-test
- A significant increase in the score of the upper limb coordination subtest of the Bruininks-Oseretsky Test of Motor Proficiency-Long Form (BOTMP-LF) in the cup stacking group will be observed when comparing the pre-test to the post-test
- A significant decrease in cup clearance height for the cup stacking group will be observed in the kinematic analysis when comparing the pre-test to the post-test
- A significant decrease in up stack time for the cup stacking group will be observed in the kinematic analysis when comparing the pre-test to the post-test

Significance of the Study

Physical educators are always looking for scientific data to support the inclusion of physical education in an academic program in the schools. This study tested one of the many sports that are practiced in physical education in order to measure the scientific validity of cup stacking. Minimal scientific data exists on the effects of cup stacking to support the manufactures claims. The scientific data from this study could act as quantifiable information about cup stacking activities that are taught in over 6600 physical education and after school programs. This study's results will assist physical educators in determining if cup stacking has a place in a physical education program.

Operational Definitions

- Ambidexterity – ability to use both sides of the body equality
- Anti-phase movement – when both sides of the body are doing opposite things (Schmidt & Lee, 1999)
- Attractors – perferred behavioral states of coordinated movement (Magill, 2001)
- Augmented feedback – term used to describe feedback that comes from an external source (Magill, 2001)
- Bimanual coordination – a motor skill that requires the use of both arms at the same time; may require the same or different spatial and/or temporal characteristics (Magill, 2001)
- Bruininks-Oseretsky Test of Motor Proficiency – a battery of subtests that uses norms to determine a level of overall motor proficiency
- Continuous task – motor skill that does not have a clearly defined beginning and end (Magill, 2001)
- Coordination – moving the body and/or limb relative to environmental objects and events (Magill, 2001)
- Cup Stacking – sport in which competitors upstack and downstack twelve specially designed cups against the clock (Speed Stacks, Inc., 2002)
- Discrete task – motor skill with a clearly defined beginning and end (Magill, 2001)

- Down stacking – term used for stacking the cups “down” (World Cup Stacking Association, 2003)
- Dynamic Systems Theory – a model to describe and explain the control of coordinated movement that emphasizes the role of the task, environment, and organism constraining each other
- EEG – electroencephalography, a measurement of electrical potentials of the brain (Cox, 2002)
- fMRI – functional magnetic resonance imaging, a measurement technique that assesses active brain tissue (Serrien, D., Nirkko, A., Loevblad, K., & Wiesendanger, 2001)
- Handedness – the hand with which the subject is most comfortable performing motor tasks
- Hand-eye coordination – action of the hands moving in response to a visual stimulation
- In-phase movement – when both sides of the body are doing the same thing (Schmidt & Lee, 1999)
- Motor proficiency – the ability to complete a skill in the easiest way possible
- Physical Education – part of a school’s curriculum that focuses on the psychomotor, affective and cognitive domains of development
- Physical Educator – person who teaches physical education
- Reaction time – time between the onset of the signal and the start of a response (Magill, 2001)

- Relative phase – difference between the right and left side angles of a bimanual movement (Schmidt & Lee, 1999)
- Soda Pop Test – well documented test to measure hand-eye coordination (Hoeger & Hoeger, 2002), involves placing full soda cans in a series of circles in a specified order
- Sport – competitive physical activities governed by rules (Wuest & Bucher, 1999)
- Unimanual movement– the ability to move one side of the body independent of the other side
- Up stacking – term used for stacking the cups "up" (World Cup Stacking Association, 2003)
- Yardstick Test – well established test for measuring reaction time (Hoeger & Hoeger, 2002) that involves grasping a yardstick that is dropped vertically as fast as possible

Assumptions

The following are assumptions of this study: (a) the participants did not practice cup stacking outside of the experimental setting, (b) the participants did not participate in activities that purposefully enhanced upper extremity or bimanual coordination, and (c) all participants were motivated to give their best effort in the sport of cup stacking throughout the duration of the study.

Limitations

The following were limitations of this study: (a) participants may have developmental differences, (b) participants may have previous experience with the sport of cup stacking, (c) participants may have upper limb anatomically anomalies,

(d) participants may have practiced cup stacking outside of the intervention, (e) participants may not have proper level of motivation for five weeks, and (f) the control group may have practiced activities that enhanced their coordination when the experimental group is practicing cup stacking.

Delimitations

The following delimitations for this study are: (a) students from the same class were used, (b) anyone with previous experience was placed in the control group, (c) disabled students with anatomical anomalies were allowed to participate, but their data was not be used for this study, and (d) students were asked not to practice in anything that resembles the sport of cup stacking outside of class.

CHAPTER TWO

Review of the Literature

Many motor skills require the use of two limbs for movement. Bimanual movement can be separated into symmetric bimanual coordination (moving limbs together) and asymmetric bimanual coordination (each limb doing something different). Symmetric movement occurs during activities such as rowing a boat or performing a bench press. Asymmetric movement occurs in activities such as playing a saxophone, typing, and throwing a baseball. The purpose of this study was to measure upper limb coordination changes using a five week cup stacking intervention. The specific aims of this study were to measure upper limb coordination changes with a star tracer task and two subtests of the Burininks-Oseretsky Test of Motor Proficiency, as well as to three dimensionally analyze the sport of cup stacking. We used the Peak Performance Motion Analysis System (Motus Ver. 7.3.2, Centennial, CO.) to measure cup clearance height and time to up stack.

Motor behavior studies have found that both of the limbs prefer to do the same thing at the same time (Magill, 2001). This coupling of the limbs assists in symmetrical movements, but makes asymmetrical movements difficult. This explains why it is hard to rub your stomach and pat your head at the same time. The decoupling and acquisition of new bimanual movements has been of interest to many motor behavior researchers (Fagard & Peze, 1997; Summers, Davis, & Byblow, 2002; Tayler & Davids, 1997).

The following topics are addressed: (a) a history of cup stacking, (b) brain activity during a bimanual coordination task, (c) the role of feedback in learning and retaining a bimanual skill, (d) role of handedness in bimanual skill acquisitions, (e) timing aspect of bimanual coordination, and (f) different methods to assess coordination.

Cup Stacking

Cup stacking dates back to the early 1980s (Udermann et al., 2003). Wayne Godinet, who worked for the Boys and Girls Club, developed cup stacking as a recreational activity. He originally used paper cups, although plastic cups have now taken over. The first competition was held in 1985 in southern California and gained national exposure on the "Tonight Show" with Johnny Carson in 1990 when he hosted the first live television appearance of someone demonstrating cup stacking.

The original paper cups were found to be too light and flimsy. The cups of today are made of a strong plastic with a texture gripping on the outside to prevent slipping. They have a smooth inside surface to allow the cups to slide over each other with less friction. The new cups also have holes in the bottom of them to decrease air resistance.

With the growth of the sport, the World Cup Stacking Association (WSCA) was formed in 2001. The association promotes the standardization of the sport of cup stacking and provides rules and regulations for the sport. The official WCSA Cup Stacking Rule Book (World Cup Stacking Association, 2003) has been developed by this association's board of directors. Included in the rule book are definitions of terms, proper stacking sequences, individual time competition rules, team relay competition rules, penalty points, forfeits/unsportsmanlike conduct, and how new records must be established.

Cup stacking has evolved into a sport in which participants up stack and down stack twelve specially designed cups (Speed Stacks, Inc., 2002). The participants are timed to see how fast they can do a 3-3-3, 3-6-3, and a cycle stack. The cycle stack includes a 3-6-3, a 6-6, and a 1-10-1, ending in a down stacked 3-6-3. In the past, participants were timed by someone with a hand timer, but new technology has allowed for reaction timer competition mats that are used in competitions currently.

A 3-6-3 stack is a term that means the cups are up stacked and down stacked in three stacks made up of three cups on the left, six cups in the center, and three cups on the right. The 6-6 and 1-10-1 stacks follow the same pattern. A fumble is the term used when the cups fall during the up stacking or down stacking phase. There are three types of fumbles: a tipper, a slider, and a toppler. A tipper is when the cup(s) fall off of a stack and land on the table or floor. A slider is when the cup(s) slide down onto the cup(s) that are lower in the stack. A toppler is when the down stacked group of cups falls on its side.

Speed Stacks, Inc. maintains that cup stacking positively promotes a variety of cognitive, affective, and psychomotor process. They claim that the cognitive domain is affected by improving concentration, using physical and mental activity, and involving both the body and brain. They claim that the affective domain is affected by the sport allowing everyone to succeed, promoting good sportsmanship, promoting confidence, and improving self-esteem. They claim that the psychomotor domain is affected by increasing coordination, improving ambidexterity, developing hand-eye accuracy, and improving reaction time. While there is plenty of anecdotal evidence for these claims, the amount of scientific evidence supporting them is sparse.

Since the sport of cup stacking is still fairly new, there have only been three known research studies on the effects of cup stacking and only one of them has been published. Reaction time, hand-eye coordination, motivation, and feedback have all been addressed in the existing cup stacking literature. No studies to date have attempted to measure the effect of cup stacking on coordination to date.

Fredenburg, Lee, and Solmon (2001) used cup staking as a novel task to investigate how different types of feedback affected perceptions of ability of a novel task in fourth grade students. However, they did not take direct psychomotor measurements on the effects of cup stacking. The students were assigned to one of four groups: (a) no feedback, (b) motivational feedback, (c) task feedback, or (d) motivation and task feedback. The students practiced both simple (3-3 stack) and complex (cycle stack) cup stacking skills. The researchers found no significant differences in feedback for the simple task. They did, however, find that feedback was important during the more complex task.

Udermann et al. (2003) was the first group to measure the psychomotor effects of cup stacking. They measured hand-eye coordination and reaction time in 42 second-grade students before and after a five week cup stacking intervention was given. Hand-eye coordination measurements were assessed by the Soda Pop Test (Hoeger & Hoeger, 2002). Reaction time measurements were assessed using the Yardstick Test (Hoeger & Hoeger, 2002). The students were randomly assigned to either a control or treatment group. The treatment group practiced cup stacking during their physical education period (30 minutes, 4 times per week) for five weeks. The cup stacking lessons were presented in a block practice format. They were also accompanied by physical activities to maintain the student's interest level. The control group participated in their normally scheduled activities (e.g. jump rope, parachute) during the same time. The researchers found significant differences using a two-way ANOVA with repeated measures. Both the pre and post scores for hand-eye coordination and reaction time in the treatment group were significantly better, but no significance was found for the control group. However, the authors did not address whether or not the control and experimental groups post-test scores were significantly different from each other.

Conn (2003) used cup stacking as a means to change reaction time and movement time in both the dominant and non-dominant hands. She studied 82 fourth-grade students from four different physical education classes in her study. All of the students were pre and post-tested for reaction time and movement time of both hands. She used a reaction time box and a movement time box to measure her dependent variables. The classes were separated into two groups, a treatment group and control group. The treatment group participated in a five-week cup stacking unit that used random practice rather than blocked practice with cups from Speed Stacks, Inc. This means that the cup stacking activities were randomly practiced with scooter activities and volleyball activities. The control group received no instruction in cup stacking. They participated in flag football, scooters, and volleyball units during the research project. A dependent t-test was used to determine differences with alpha set at .05. During the pretest, the researcher found no significant differences for reaction time and movement time between both of the groups. This indicated that both of the groups were similar in nature. In the post-test for the treatment group, the researcher found differences in movement time for both groups, but no significance in reaction time for either group. The researcher suggested that since movement time was the only variable that changed cup stacking may not have a desirable effect on reaction time.

Hart, Smith, and DeChant (2003) performed another study on cup stacking. The researchers measured hand-eye coordination changes in first, third, and fourth grade physical education classes (N = 104). They used three separate measures of hand-eye coordination to quantify changes. The measures included: (a) placing pennies in a cup with both hands, (b) placing pennies in a cup with the nondominate hand, and (c) placing pegs in a peg board. The researchers only found significant differences between the groups on the peg board task and concluded that a three week unit in cup stacking did not elicit measurable changes in hand-eye coordination. They also suggested that a three week cup stacking unit may not be long enough to produce changes in hand-eye coordination.

Brain Activity During Coordinated Movement

Technological techniques, such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI), will be discussed in this section relating to their importance to directly observe the brain during activity. Interhemispheric interaction and coupling/decoupling of the limbs will be reviewed in this section.

Brain activity during movements has become a major topic in psychology, sport psychology, exercise psychology, and motor behavior disciplines. Many researchers have tried to design experiments that isolate one type of movement and then look at the active part of the brain for that movement. More advanced studies have assessed a variety of movements and the correlated brain activity. Advancements in technology have allowed the use of noninvasive measurements of a working, living brain. Research projects using electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) have given new insight as to what the brain is doing during movement.

The use of fMRI is well documented as a measure to assess active brain tissue. Several recent studies (Debaere, Swinnen, Beatse, Sunaert, Van Heck, & Duysens, 2001; Jaencke, Peters, Himmelbach, Noesselt, Shah, & Steinmetz, 2000; and Serrien, Nirkko, Loevblad, & Wiesendanger, 2001) have used fMRI as a means to measure different parts of the brain during a variety of movements. The advantage of fMRI usage in human movement science is that we can assess a brain while it is in action. Debaere et al. (2001) assessed the activation of the supplementary motor area (SMA), cingulated motor cortex (CMC), premotor cortex (PMC), primary sensorimotor cortex (M1/S1) and the cerebellum using fMRI during movements of the wrist and foot. Results of this study indicated that activation in all areas during the coordinated movements exceeded the sum of the activations observed during the isolated limb movements. Also, activation of the SMA was even higher when the limb movements were in different directions compared to moving in the same directions. Serrien et al. (2001) examined bimanual function and coordination in three people with parietal lobe damage using fMRI. The subjects timing of movement was off mostly during parallel patterns. The authors concluded that the parietal lobe plays a significant role in bimanual coordination, which becomes more pronounced as the task becomes more difficult. Jaencke et al (2001) investigated the sensorimotor cortex (SMC) and supplementary motor area (SMA) activation using fMRI for unimanual and bimanual tapping tasks. Results showed that the SMC contralateral to the faster hand was more activated than the opposite side. Similar activation levels for the SMC were recorded for both the unimanual and bimanual movements. The SMA was significantly more activated during the bimanual movements. Toyokura, Muro, Komiya, & Obara (1999) investigated how much the SMA and SMC were activated during unimanual and bimanual movements using fMRI. The tasks consisted of opening and closing of the hands. The authors found that the task requiring antagonistic movement of both hands resulted in more activation of the SMA. The same task resulted in significantly higher activation for the SMC also.

The use of EEG has been used in sport psychology to measure arousal (Hatfield, Landers, & Ray, 1984) and attentional patterns (Crews & Landers, 1993), among other topics. Its use in understanding coordination dynamics in human movement science is still fairly new. This assessment technique is advantageous because it allows researchers to read direct electrical measurements from a brain in action. Serrien, Cassidy, and Brown (2003) investigated hemisphere activation during unilateral and bilateral movements using EEG signals of the primary sensorimotor cortex. The results indicate that during unimanual movment, the contralateral hemisphere predominantly organizes the movement. During coupled bimanual movements, the dominate hemisphere mainly controlled the movement. Cardoso de Oliveira, Gribova, Donchin, Bergman, and Vaadia (2001) studied the corpus callosum's effect on bimanual coordination of primates. They used EEG measures to assess if differences in activity of different hemispheres exist during movement. The results indicated that both of the hemispheres were equally active during a bimanual task. The authors attribute the coupling of arms to the equal hemisphere activation. Gerloff and Andres (2002) examined interhemispheric interaction during bimanual coordination. They used EEG to measure task-related coherence and task-related power. They found that hemispheric interaction coupling was very important during the early stages of acquisition of a novel bimanual task. The authors suggest that these dynamic changes in the interhemispheric interaction cause the creation of efficient manual routines.

Interhemispheric transfer rate has also been assessed indirectly. Fagard and colleagues (2001) studied the effect of the development of interhemispheric communication on age-related change in bimanual coordination. Interhemispheric communication was assessed by comparing the time to respond to a visual stimulus when the hemisphere perceiving and controlling the stimulus were the same (uncrossed condition) vs. when the hemisphere perceiving and controlling the stimulus were different (crossed condition). The results indicated that the crossed-uncrossed condition difference decreased with age. Results also indicated that the crossed-uncrossed difference was related to the difference in performance between mirror and parallel movements on the bimanual task. This research indicates that the brain was better able to transfer information as the subject aged.

Other parts of the brain have been studied during movement. Kermadi, Liu, & Rouiller (2000) measured the level of activity of task related neurons in the dorsal premotor (PMd), cingulate (CMA), supplementary motor cortical area (SMA), primary sensory motor cortex (M1/S1), and the posterior parietal cortices (PPC) in two trained moneys. Tasks included a bimanual task, left hand only, and right hand only. This study found that the PPC exhibited the greatest number of bimanual neurons. It also concluded that the five cortical areas (PMd, CMA, PPC, SMA, and M1) all participate in the control of bimanual movements.

Obihi, Haggard, Taylor, and Pascual-Leone (2002) examined the effect of transcranial magnetic stimulation (rTMS) on unimanual and bimanual activity. Their study consisted of rTMS at 1 Hz for five minutes to create a temporary virtual lesion of the rostral portion of the supplementary motor area (SMA). The subjects then completed a task of opening a drawer with the left hand, catching a ball with the right hand, and then placing the ball in the drawer with their right hand. The researchers looked at both unimanual and bimanual intervals. They found that none of the unimanual intervals were affected by the rTMS, but the variability of the bimanual interval increased with the rTMS. The authors suggested that the SMA may play an important role in controlling bimanual movements.

One study attempted to define normal development of bimanual coordination. Marion, Kilian, Naramor, & Brown (2003) compared the bimanual coordination of children ages 6 to 15 using the computerized Bimanual Coordination Test (cBCT). Results indicated that left and right hand unimanual motor speed was significantly correlated with age. The authors concluded that age was significantly associated with accuracy of performance in the bimanual tasks.

Another investigated the changes in bimanual coordination when different parts of the brain are removed. Eliassen (1998) looked at bimanual coordination before and after a human subject underwent complete callosotomy in two stages. This first surgery removed the anterior two-thirds of the callosum and the second removed the posterior one-third. Removal of the anterior portion affected the temporal aspects of coordination. Removal of the posterior portion disrupted spatial coordination and those temporal aspects related to the visuospatial demands of the task. The author suggests that the frontal areas coordinate timing and the parietal areas control the visuospatial integration between the limbs.

Lastly, an attempt has been made to model neural networks of bimanual coordination. Farrar and Ziper (1999) looked at controlling the movement a pair of arms using two different mechanisms. This study used computer robotic modeling to make predictions about what may be observed in the brain systems serving bilateral coordination.

The study of brain activity on coordinated movement is a vast and ever changing field. Researchers are now able to indicate which areas of the brain are active during different movements. The use of EEG and fMRI has given researchers a noninvasive technique to study a living brain during movement. This research is now being used to create models of bimanual coordination so that researchers can better understand how the brain controls human movement.

Feedback

This third section will cover the role of feedback in the learning and retaining of a bimanual skill. Advantages and disadvantages of different types of feedback will be reviewed. This includes when, how much, and what kind of feedback is appropriate. A comparison of age-related feedback will also be presented.

The role of feedback has been repeatedly studied in physical education and sport studies journals. When, how much, and what kind of feedback is appropriate is now understood in the literature. Since the learning and retaining of a bimanual task is considered complex (Fredenburg, Lee, & Solmon, 2001), studies were needed to understand the best type of feedback to give along with when to give it.

The role of augmented feedback has been studied. Hodges and Lee (1999) investigated the role of specific and general instruction to learning a new bimanual task.

The results indicate that while both groups learned the task in different ways, the specific instruction group regressed back to a previously stable pattern of coordination when a secondary task transfer test was given. This indicates that discover learning may facilitate the learning of a complex bimanual coordination task. Wishart, Lee, Cunningham, & Murdoch (2002) investigated the effects of augmented visual feedback for older vs. younger adults in the learning of a new bimanual coordination pattern. Both the younger and older groups benefited from the concurrent visual feedback, but the younger group gained less from the concurrent feedback relative to terminal feedback. This suggests that older adults are more sensitive to the structure of practice conditions. Wrisberg, Dale, Liu, and Reed (1995) studied the effects of augmented information on the learning of a new task. The subjects performed a two handed coordination task that consisted of moving a steel ball through a maze. The subjects were separated into three groups. While the control group received no augmented feedback, the two experimental groups got either visual aids or a cognitive strategy. A retention and transfer test was also given. The results indicated that the practice conditions differentially influenced the search strategies of the subjects. This means that all of the conditions produced different results.

Different types of visual feedback have been studied. Hodges, Chula, and Franks (2003) investigated the role of video feedback to the learning of a novel bimanual coordination pattern. The group that received the augmented video feedback showed better performance in acquisition and retention when compared to the no-feedback group. The research also found that the video feedback group was better able to distinguish between correct and incorrect movements during error-decision tests. Swinnen, Lee, Verschueren, Serrien, & Bogaerds (1997) investigated the learning and transfer of a new bimanual task under three different feedback conditions. The three conditions were: a) blindfolded, b) normal vision, and c) with concurrent relative motion information. The results indicated that the group that received the concurrent relative motion information did the best on both the acquisition and transfer performance.

Swinnen, Walter, Lee, & Serrien, (1993) studied a subject's capability to decouple limb using various sources of feedback. Despite a tendency to be synchronized, the results indicated that the subjects were able to decouple the limbs as a result of practice with augmented feedback. It was found the detailed knowledge of movement kinematics (KP) was not more effective than global outcome information (KR) for the decoupling task. The authors concluded that KR may be more important than previously thought and that the learning of a new coordination pattern involves the suppression of preexisting preferred coordination patterns.

Age related differences in feedback processing have been studied. Swinnen, Verschueren, Bogaerts, Dounskaia, Lee, Stelmach, and Serrien (1998) studied the learning and transfer of a new bimanual task in adolescents and elderly subjects. The elderly's performance levels and rate of improvement were smaller than that of the adolescent groups. The authors hypothesized that the elderly's performance was attributed to the decreased capability to overcome preferred coordination patterns to learn new ones.

Tsutsui and Imanaka (2003) looked at the effect of manual guidance on acquiring a new bimanual coordination pattern. Thirty-two subjects were given manual guidance by an expert in the experimental task. The results indicated that the manual guidance did improve performance, but it was less effective than physical practice.

Lastly, Hodges (2002) conducted four experiments to examine how pre-practice information affected the early stage of skill acquisition for a novel task. It was found that movement demonstrations and instructions were of little use in the early stage of skill acquisition, if the information pertaining to goal attainment was available. The author concluded that these instructions may help refine movement at a later stage.

Handedness

This fourth section will discuss handedness in bimanual coordination. This section will include some current literature that discusses movement amplitudes of both the right and left hands and attentional concerns of handedness. Also, the question of which hand leads in movement will be explored.

Several aspects of preferred handedness have been studied in the literature. Attentional demands, force produced, and movement amplitudes have all been quantified in previous studies. This section will review the current literature in handedness as it pertains to bimanual coordination. Franz, Rowse, and Ballantine (2002) investigated whether or not handedness determines which hand leads in a bimanual task. The subjects were tested on variations of bimanual circle drawing. This included both parallel and mirror symmetrical movements. The authors concluded that hand dominance does not usually determine which hand leads in a bimanual task. Hopkins and Roennqvist (1998) discussed several arguments on handedness. They suggested that handedness has a different development origin than the mechanisms for speech and language. They argued that there is no simple task that will provide a valid assessment of handedness during the first year of life. More importantly, they suggested that studies on handedness should be more sensitive to the role of the task. Lastly, they argued that the development of handedness should be addressed by models that incorporate hand preference into different modes of bimanual coordination. Amazeen, Amazeen, Treffner, and Turvey (1997) studied the attention and handedness in bimanual coordination dynamics. Their participants were asked to manipulate a locking task. Both handedness and direction of attention was changed during the experiment. The authors found that when attention was directed toward the preferred hand, the variability of relative phase would be lower. This supports the dynamical perspective of movement which states that, with experience, the human system will find the easiest way to accomplish a task.

Spijkers, Heuer, Steglich, and Kleinsorge (2000) investigated the movement amplitudes of both the right and left hands in two overlapping unimanual tasks. They found that differences in reaction time between the two hands diminished over practice trials. This supports the idea of coupling during a bimanual movement. Conn (2003) studied the effects of cup stacking on fourth grade students. She assessed both reaction time and movement time. She found no significant differences in hand dominance in her population of fourth grade students. Her data revealed no differences in reaction times, but a significant difference in post-test movement times for both the control group and the experimental group.

Bimanual Coordination Timing

This fifth section will cover timing aspects of bimanual coordination. This section will discuss some of the many topics that have addressed timing issues in bimanual coordination. Acquisition and different temporal demands will be discussed as it pertains to bimanual movements.

There are two models that have been presented for the timing of bimanual coordination. Kelso, Southard, and Goodman (1979) theorized that a temporal relationship between the hands exists, explaining the act of coupling. Their classic study of more than 20 years ago showed that when each limb is presented with two different tasks based on timing, they attempt to match each other. They also found that the arm that presented the more difficult task influenced the arm doing the less difficult task. Marteniuk, MacKenzie, and Baba (1984) proposed that separate commands are given to each limb and that the commands arrive at the same time. They argue that a generalized motor program controls the arms. Both of these models suggest that the timing of a bimanual task is very complex and may be affected by many factors.

Tayler and Davids (1997) tested the two current models of bimanual coordination. They used a real world catching task in which the required movement was dependent of the ball path. The kinematic data showed that the right and left limbs had similar time to peak velocity and total distance moved, which supports the model of Kelso et al. (1979). The authors concluded that timing was an essential variable in bimanual coordination patterns.

Carson, Riek, Byblow, Abernethy, and Summers (1999) looked at the timing of intralimb coordination. The authors researched the changes of self-selected movement frequencies by changing the characteristics of the limb and effects of practice. Twelve subjects practiced a flexion/extension movement of their elbow and wrist at a self selected pace while grasping one of three weighted dowels (no-weight (0.03 kg), light weight (0.5 kg), and heavy weight (1.0 kg)). The subjects practiced this movement for three weeks for a total of 120 trials. The researchers found that following the 120 trials, movement frequencies were notably higher. When they added mass to the system, it had a nonlinear effect. The movement frequencies of the no-weight and light weight conditions were similar, while the addition of the heavy weight caused the movement system to be considerably slower. The authors suggested that the changes made by the system were due to mechanical and neuromuscular constraints.

Summers, Davis, and Byblow (2002) studied the effects of tempo on the ability to learn a task in both the preferred and non-preferred hand. The researchers found that differences between the two hands appeared when the acquisition of the task was still fairly new, but both hands produced equivalent stability by the end of the training session. The authors concluded that the trend to more toward stability was involved with the reorganization of the inherent dynamics. This supports other reported research stating that the human systems tend to become more stable and efficient in the environment with experience. Lantero (1998) measured the influence of temporal demands on continuous bimanual movements with and without a spatial component. He investigated his subjects performing a bimanual movement (tapping and circle drawing) while changing the timing of each hand randomly. He found that the temporal demands during tapping were easy, while the temporal demands for circle drawing were hard. He concluded that timing is an emergent property of the task, not an abstract movement that is imposed upon the task. Dean (2002) looked at rhythmical and discrete movement patterns in the upper extremity. He conducted five experiments to measure interactions between discrete and rhythmic movements. He found rhythmic movement constrains the timing of the beginning of the discrete movement. He also found that when the rhythmical and discrete movements were put together in a bimanual task, the speed of the discrete movement increased the frequency of the rhythmic movements.

Court, Bennett, Williams, and Davids (2002) assessed fluctuation and relaxation times for both anti-phase and in-phase movements. Relaxation times were defined as the time it takes to return to a stable mode following the movement. Fluctuation was defined as the mean standard deviation of the relative phase across individual frequency plateaus. The authors found that relaxation times were not statistically different among participants, frequencies, and coordinative modes. They did find that fluctuations were significantly greater in the anti-phase mode when compared to the in-phase mode. This indicates that when the left and right sides of the body are doing opposite movements (anti-phase movement), the body system is less stable.

Assessment of Coordination

This last section will cover the different assessments of coordination. This section will include the content of the chosen tests along with a brief description of other tests used in testing motor coordination and motor proficiency. Validity and reliability measures for each instrument will be reported. Other quantitative assessments of coordination will also be discussed.

There are many tests to measure different aspects of motor behavior. This final part of the literature review will mostly cover the scientific data that backs up the tests that will be used for this study. Other tests will be mentioned briefly.

The Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) is a battery of eight subtests comprising of 46 items (long form version). The test is norm-referenced.

There is a short form version that consists of 14 items that can be used as a quick screening item. This test measures gross and fine motor proficiency for children ages 4½ to 14 ½ . The long form takes about 45 to 60 minutes to administer. The short form takes about 15 to 20 minutes to administer. The test was standardized using 765 school aged children. Test-retest reliability for the long and short form is 0.87 and 0.86 respectively. Other researchers have found this test to be useful for discrimination between children with gross motor dysfunction and "normal" children (Haubensticker, 1981). That could perhaps be why this test was the number one ranked motor assessment test used by adapted physical education teachers at one time (Ulrich, 1984).

Verderber and Payne (1987) investigated a comparison of the long and short forms for the BOTMP. The researchers found that a correlation existed between the two forms. However, a t-test showed that the forms were significantly different. The authors concluded that placement in an adapted physical education class may be dependent on the form used. They suggested that the long form be used for placement tests.

Wilson, Kaplan, Crawford, and Dewey (2000) measured the interrater reliability of the BOTMP long form. They used six therapists as their subjects. The authors found that while some consistency was found, other parts of the test were found to be different. The authors suggest that the BOTMP could be a limitation to research in interrater reliability is taken into consideration. For that reason, only the Principle Investigator will rate the subjects on the BOTMP long form for this study.

Kheng Tan, Parker, and Larkin (2001) measured the concurrent validity of two different motor tests that are used to identify children with motor impairment. The McCarron Assessment of Neuromuscular Development (MAND) and the BOTMP short form were used for this study. The researchers found that the MAND was a more accurate discriminator of motor impairment (MI). They concluded that the MAND is a more valid test for the identification of MI in Australian children.

The BOTMP short form has also been used by classroom teachers. King and Dunn (1989) assessed a classroom's ability to accurately observe student's motor performance. The researchers found a high degree of variance within the low and high groups. They concluded that classroom teachers are less accurate at observing low motor performance than they are at observing high motor performance.

Another instrument used in assessing students is the Movement Assessment Battery for Children. Croce, Hovat, and McCarthy (2001) conducted a test-retest reliability measure of this instrument. A high correlation (r = .71) was found between this instrument and the BOTMP short form. The authors concluded that this instrument was a reliable and valid measure of motor ability in children ages 5-12.

Maeland (1992) examined three different methods to assess clumsiness. They were the Test of Motor Proficiency (TMP), the Test of Motor Impairment (TOMI), and the teacher's judgment. While all three procedures identified about the same percentage of the 360 children (5-5.6%), the identified groups were quite different. The researcher concluded that the lack of agreement demonstrates the difficulty in properly assessing motor coordination problems.

The reliability and validity of the previously mentioned TOMI was tested by Riggen, Ulrich, and Ozmun (1990). Absolute reliability of the test was calculated using a standard error of measurement technique. Concurrent validity was figured using the BOTMP short form. The researchers found that the TOMI was both reliable and valid.

The Basic Motor Ability Test – Revised (BMAT-R) is a test that measures selected large and small muscle control responses (Payne & Isaacs, 2002). It was originally developed in 1974 and revised in 1978 by Arnheim and Sinclair (1979). It is a battery of tests that can be used to measure 4 to 12 year old children. It takes about 30 minutes to administer and the reliability for the entire test has been shown to be .93.

The Ohio State University Scale of Intra-Gross Motor Assessment (OSU-SIGMA) is a criterion-referenced test that measures the motor behavior of preschool and elementary children, along with young children with mental retardation. It used 11 fundamental motor skills in four developmental levels. Interjudge agreement ranges from 0.50 to 1.00 and intrajudge agreement ranges from 0.67 to 1.00.

The Fundamental Motor Pattern Assessment Instrument was developed in the latter 1970s. It measures developmental changes over time in six fundamental movement patterns. Each movement pattern is scored in one of three stages of development. Test-retest reliability performance was reported at 88.6 percent, while interrater objectivity was reported ranging from 80 to 95 percent (McClenaghan & Gallahue, 1978).

The Test of Gross Motor Development – 2 (TGMD-2) is an assessment that measures the performance of children ages three to eleven years old. It measures 12 motor skills that are divided into two subsets: locomotor skills and object-control skills. Reliability coefficients range from .84 to .91. The test can be administered in 15 to 20 minutes. Ulrich (1984), along with Suomi and Suomi (1997), suggests that their research shows that the TGMD-2 can be used with minimal training.

Another way to measure motor behavior is with a two handed coordination task (Schmidt & Lee, 1999). This piece of equipment allows the subject to follow a target by moving two handles in a coordinated fashion. The handle on the right controls right-left movement and the handle on the left controls forward-backward movement. The subjects attempt to follow a light with their stylus. The piece of equipment measures total time on task, or on the light.

Unimanual movement can be measured by a pursuit rotor. This device is similar to the two handed coordination task, but only measures one hand at a time. It contains a target that is embedded in a turning surface. The subject holds a stylus and attempt to keep its tip on the target while it is moving. Cremades, Smith, and Zhang (1997) used the pursuit rotor to measure a subject's ability to perform two tasks at once, such as driving a car and talking on a phone. The researchers found that when more than one task was presented, the performance on both tasks decreases.

There have been many proposed ways to assess intersegmental coordination over the years. One of the first ways was introduced by Grieve (1968, 1969). This researcher created relative motion plots (i.e. angle-angle diagrams). This is a graphical representation of angle values of one joint plotted against the angle values of another joint. While this technique has been used as a means of assessment in many different types of studies, such as coordination between different speeds (Charteris, 1982) and differences between normal and pathological gait (Hershler & Milner, 1980a, 1980b), it is a better form of qualitative analysis than quantitative analysis. While attempts have been made to quantify angle-angle plots (Goswami, 1998; Hershler & Milner, 1980a, 1980b; Sidaway, Heise, & Schoenfelder-Zohdi, 1995), each technique has its own limitation. Limitations include complexity of the analysis and problems creating an angle-angle plot into a geometric shape to analyze. Freeman (1974) purposed an encoded chain technique for angle-angle plots. This coding scheme created a shape of an image using an 8-point scale based on the frame to frame direction of the line segment formed by two consecutive data points. The problem with this technique is that it takes ratio scale data and turns it into nominal scale data. This could result in the loss of important information and also limits the statistical techniques that can be used. A vector coding technique purposed by Tepavac and Field-Fote (2001) uses frame to frame analysis, but leaves the data in a ratio scale form. This technique creates frame by frame vectors that have defined direction and magnitude. Using their technique, a value of *r* is found through analyzing both the magnitude and direction of each frame by frame vector. The value of *r* ranges from 0 to 1, with a value of 1 meaning that all of the cycles are identical and a value of 0 meaning that the data points from all the cycles are near random.

Summary

Despite recent advances in the understanding of many components of bimanual coordination, researchers are not certain how the human body controls its movements (Magill, 2001). It has been established that the arms are coupled, that is, they prefer to move in the same pattern at the same time. It has also appears that in-phase movements (extending and flexing both arms at the same time) are more dominate than anti-phase movements. We have found through research that we can learn to decouple the limbs with practice. Although we know that these movements can be acquired over time, we do not understand the mechanisms in which they happen. Verschuern, Swinnen, Cordo, and Dounskaia (1999a) support accumulating research that suggests proprioceptive feedback from a successful performance of asymmetrical movement is important in acquiring a bimanual coordination pattern.

There are two topics that have been indirectly addressed within this literature review. They are the two types of control systems for human movement: the information processing model (IP) and the dynamical systems theory model (DST). Both systems have been researched in the field of motor behavior and there is support for both models.

The researchers that support the IP models suggest that a generalized motor program (GMP) controls limb movement, but disagreement exists of whether one GMP controls both limbs or a separate GMP controls each of the limbs. Researchers that support the DST model suggest that experience with the task and environment, along with changes in the organism account for the acquisition of bimanual coordination. There is some support for a combination of both the IP and DST theories when learning a new bimanual task.

The research in bimanual coordination is vast and ever changing. New technology (fMRI and EEG) allows us to see the human brain while we are doing movement activities. When, how much, and what kind of feedback to give is better understood now than in the past. The role of handedness allows use to design better experiments taking hand preferences and differences into account. Timing aspects in bimanual coordination allows us to measure intralimb differences and changes in coordination over time. Lastly, the availability of many assessments in motor behavior allows the researchers to choose a valid and reliable measure for their study.

The literature cited in this chapter has shown evidence of what we know about upper limb coordination. Topics of how to obtain, change and assess upper limb coodination have been explored. There are still many gaps in the literature about different types of interventions that change upper limb coordination patterns. Specifically, the use of cup stacking as an intervention to change coordination patterns is not well documented.

CHAPTER THREE

Methods

The purpose of this study was to measure upper limb coordination changes using a five week cup stacking intervention. The specific aims of this study were to measure upper limb coordination changes with a star tracer task and two subtests of the Burininks-Oseretsky Test of Motor Proficiency, as well as to three dimensionally analyze the sport of cup stacking. We used the Peak Performance Motion Analysis System (Motus Ver. 7.3.2, Centennial, CO.) to measure cup clearance height and time to up stack.

Participants

The participants (N=26) for this study were students from a middle school in the southeastern United States. This middle school consists of students in grades six through eight. All of the students received physical education every other day. Therefore, the students receive physical education instruction three times one week and then two times the following week.

The participant's age ranged from 11 to 12 years old. The sixth grade takes physical education one semester and a fine arts class the other semester. The participants for this study had just started their physical education instruction semester. They were recruited by watching a presentation of cup stacking and by an informational flyer which was sent to their home. One week following the informational flyer, the consent and assent forms were sent home with the participants. None of the participants had any prior experience in of cup stacking and the hypotheses of this study. All participants were allowed to participate, but the data from a student with an upper limb disability was not be used for this study. All of the participants were encouraged not to participate in activities resembling cup stacking outside of the class. All participants were required to give their assent and have their legal guardian sign a consent form before participating in the study.

Instrumentation

Four instruments were used for this study. They included: (a) a school pack from Speed Stacks, Inc. (b) a star tracer task from Lafayette Instruments, (c) the Bruininks-Oseretsky Test of Motor Proficiency-Long Form, and (d) the Peak Performance Motion Analysis system.

Cup Stacking Equipment

The school pack from Speed Stacks, Inc. consists of 30 sets of cups made specially for cup stacking. Each set includes 12 cups. The school pack also includes a reaction timer for competition, a set of mini cups, and a set of weighted cups. Lesson plans that accompany the school pack and other printed cup stacking resources were adapted for this study.

Star Tracer Task

The star tracer is a quantitative measure of upper limb coordination. This piece of equipment allows the participant to follow a star shape with a stylus by moving two handles in a coordinated movement. The handle on the right controls right-left movement of the stylus and the handle on the left controls forward-backward movement of the stylus. Quantitative measurements of total time it takes to get around the star and the number of times off the star (errors) were being taken for this study.

Bruininks-Oseretsky Test of Motor Proficiency

The Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) is a battery of eight subtests comprising of 46 items (long form version). The test is norm-referenced. There is a short form version that consists of 14 items that can be used as a quick screening item. This test measures gross and fine motor proficiency for children ages 4 ½ to 14 ½. Test-retest reliability for the long form (LF) and short form (SF) is 0.87 and 0.86 respectively (Croce, Hovat, & McCarthy, 2001). The long form was used in this study since previously cited research indicated that the long form is a better determinate of motor proficiency. Two subtests of the long form were used for this test. The bilateral coordination subtest and upper limb coordination subtest sections were scored by the investigator. The investigator practiced administering the test during a pilot study. The bilateral coordination subtest consisted of the following tasks: (a) tapping feet alternately while making circles with fingers, (b) tapping foot and finger on the same side synchronized, (c) tapping foot and finger on the opposite side synchronized, (d) jumping in place – leg and arm on the same side synchronized, (e) jumping in place – leg and arm on the opposite side synchronized, (f) jumping up and clapping hand, (g) jumping up and touching heels with hands, and (h) drawing lines and crosses simultaneously. The upper limb coordination subtest included the following tasks: (a) bouncing a ball and catching it with both hands, (b) bouncing a ball and catching it with preferred hand, (c) catching a tossed ball with both hands, (d) catching a tossed ball with preferred hand, (e) throwing a ball at a target with preferred hand, (f) touching a swinging ball with preferred hand, (g) touching nose with index fingers – eyes closed, (h) touching thumb to fingertips – eye closed, and (i) pivoting thumb and index finger. Both of these subtests have their own norms and were scored independently of each other.

Videography

The Peak Performance Motion Analysis System consisted of three JVC 60 Hz cameras (JVC Professional Products Company, Denver, CO) placed in the front and to the left and right of the participant. It also consisted of a three high speed Panasonic VCRs (Secaucus, NJ) and recorded on JVC Super VHS ET videocassette recorders (JVC Professional Products Company, Denver, CO). The Peak Motus 7.3.2 Motion Measurement System (Peak Performance Technologies, Inc., Centennial, CO) was used to reduce and analyze the data from the Super VHS. Average cup clearance, as defined as the movement of the knuckles in the Y direction was analyzed for this study. Time to up stack the 6-6 stack was also analyzed. The reliability score with the investigator's manual digitization compared to the computer's automatic tracking ranged from .78 to .91.

Procedures

Pilot work was performed the semester prior to the study. The investigator assessed a college aged sample population on the star tracer along with the bilateral coordination and upper limb coordination subtests of the Bruininks-Oseretsky Test of Motor Proficiency. The investigator examined the use of a three camera system versus a four camera system for kinematic capture. It was found that the three camera system was sufficient for the movements in cup stacking. The investigator found that the use of a vector coding system described in the literature review was not an appropriate analysis technique for the movements in cup stacking. The use of the vector coding system requires movements to be repeated in a similar pattern, such as walking. The movements in cup stacking are too variable in nature, therefore the technique of assessing movement in the Y directing of the hands was used as a quantifiable variable to assess kinematic changes in cup stacking.

Prior to day one of the experiment, all of the students were assessed on the star tracer task and the two subtests from the Bruininks-Oseretsky Test of Motor Proficiency during their regular physical education class. The star tracer required the students to control a single stylus around a star shape. In this task, both arms move independently to migrate the stylus. Both time around the star and errors, as defined by moving the stylus off the star, were compiled. The Bruininks-Oseretsky Test of Motor Proficiency subtests were given to the students' one at a time and scored independently of each other. On day one of the experiment, all of the students in the sixth grade physical education class received the first instructional lesson in cup stacking. Following the initial lesson, the students were brought to the Biomechanics Laboratory at Barry University and were asked to perform the 6-6 stack they had just learned in front of the cameras in order for kinematic data to be recorded. They were then placed randomly into two groups. One group served as the control group and did not receive any more instruction or practice time with cup stacking. The second group served as the cup stacking (experimental) group. They received cup stacking practice and instruction everyday of their physical education class, which is every other day.

At the beginning of every physical education class during this experiment, the control group separated from the cup stacking group for 15 minutes and performed fitness activities for a warm-up. The cup stacking group received cup stacking instruction for the first 15 minutes of class. After the two separate warm-up sessions, the class was brought back together and the regular physical education teacher carried out her regularly scheduled lesson. The only difference between the two groups was that the cup stacking group received cup stacking instruction while the control group did fitness activities.

The experiment lasted a total of five weeks. The cup stacking lessons were adapted from the instructional lessons that Speed Stacks, Inc. provides with the school pack, along with other printed and resources. Items taught during the five week instructional lessons included the 3-6-3 stack, 6-6 stack, and the 1-10-1 stack. This indicates that the students were taught how to up stack and down stack the cups so that they make a pyramid of three cups, six cups, and three cups (3-6-3 stack) and then can transition into the other stacks. Relays and timed competitions accompanied the lessons. Feedback was given in a specific, positive, immediate, and corrective manner by the certified physical education investigator. All of the students were again tested on all of the tests after the fifth week of cup stacking.

Design and Analysis

The scoring of the star tracer task included time to move the stylus around the star and the number of errors committed during the total time. Errors were defined as any time the stylus moved off the star shape. Raw scores on the Bruininks-Oseretsky Test of Motor Proficiency subtests were compiled on the scoring sheet. A total score was calculated as defined by the scoring section in the testing manual. The raw scores were then converted to norm values for age range as defined in the testing manual.

We calculated efficient movement in cup stacking as the measurement of the vertical component of cup clearance. In biomechanical terms, the difference between the maximum knuckle Y value during each up stack to the minimum knuckle Y value when the cup is placed down indicated cup clearance height. The difference between the Y values at the peak and the minimum was defined as the cup clearance. The 6-6 stack requires three upward movements to complete the stack. The average of the three cup clearances were used to determine the average cup clearance for each individual. The time to complete each up stack was also recorded.

A one-way MANCOVA was used for this study. The independent variable was cup stacking instruction. The dependent variables for this study were the post-test star tracer time, post-test star tracer errors, post-test bilateral coordination score, post-test upper limb coordination score, post-test up stack time, and post-test cup clearance height. All pre-test scores were used as a covariate to investigate differences between groups in the post-tests. Once significance was found in the MANCOVA test, follow-up univariate ANOVAs were used to determine differences between specific variables. Significance differences were evaluated with alpha set at 0.05. Data sets that included outliers' two standard deviations above the norm were discarded prior to analysis of the data.

CHAPTER FOUR

Results

The sport of cup stacking is used in over 6600 physical education and after school programs in the United States. The leading company that manufactures and markets the cups for this sport is called Speed Stacks, Inc. The company claims that cup stacking promotes bilateral coordination. Although anecdotal evidence supports this claim, there is sparse scientific behind the marketing claims of the manufacturer. The purpose of this study was to measure upper limb coordination changes using a five week cup stacking intervention. The specific aims of this study were to measure upper limb coordination changes with a star tracer task and two subtests of the Burininks-Oseretsky Test of Motor Proficiency, as well as to three dimensionally analyze the sport of cup stacking. We used the Peak Performance Motion Analysis System (Motus Ver. 7.3.2, Centennial, CO.) to measure cup clearance height and time to up stack.

This study required the participants to complete three novel motor control tasks before and after a five week cup stacking intervention. Half of the participants were placed in the cup stacking group and half were placed in the control group. The cup stacking intervention consisted of a five week treatment of cup stacking as a warm-up activity for their physical education class. The control group participated in fitness activities as their warm-up for their physical education class. The warm-up sessions lasted for 15 minutes and then both groups were brought together for their normal physical education curriculum the remainder of the time.

Participants (N = 26) were 13 male and 13 female students in a sixth grade physical education class (age 11.68 ± .47 years). Most (N = 21/26) had never seen cup stacking before and all had not participated in a cup stacking program prior to this study.

A one-way MANCOVA was used to analyze the results. The independent variable for this study was cup stacking instruction. The dependent variables for this study were the post-test star tracer times, post-test star tracer errors, post-test bilateral coordination scores, post-test upper limb coordination scores, post-test up stack times, and post-test cup clearance heights. All pre-test scores were used as a covariate to investigate differences between groups in the post-tests Significance differences were evaluated with alpha set at 0.05.

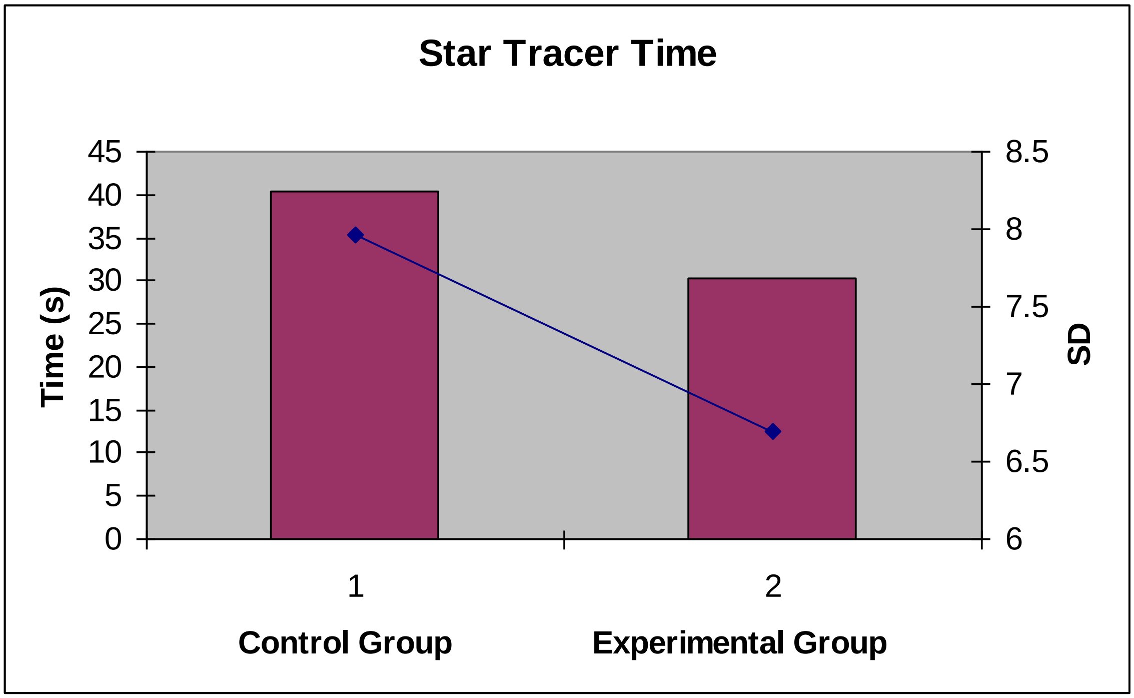
Results of the Multivariate Tests

Two of the variables investigated showed significance. The groups were significantly different (*Lambda*(6,12) = .749, $F = 5.98$, $p < .005$) in the star tracer post-test times when the star tracer pre-test times were used as a covariate. The groups were also significantly different (*Lambda*(6,12) = .359, $F = 3.57$, $p < .05$) in the time to up stack when the upper limb coordination scores were used as a covariate. All other variables showed no significance between groups in the post-test when the pre-tests were used as a covariate.

Star Tracer Time

A one-way MANCOVA was calculated examining the effect of cup stacking on the post-test star tracer time. A significant effect was found (*Lambda*(6,12) = .749, $F = 5.98$, $p < .005$) in the star tracer post-test times when the star tracer pre-test times were used as a covariate. Follow up univariate ANOVAs indicated that the post-test star time was significantly lower in the cup stacking group ($F(1,17) = 19.28$, $p < .0001$). Figure 1 shows the means and standard deviations for the post-test star tracer time for each group. The mean time for the control group was 40.28 ± 7.96s, while the mean time for the experimental group was 30.25 ± 6.69s.

Figure 1: Star Tracer Time for the Post-test



Star Tracer Errors

A one-way MANCOVA was calculated examining the effect of cup stacking on the post-test star tracer errors. No significant effect was found ($Lambda(6,12) = 0.42$, $p > .05$). Cup stacking had no effect on the number of errors on the star tracer task. Descriptive statistics for the star tracer post-test are outlined in Table 1.

Table 1

Descriptive Statistics for the Star Tracer

		Mean	SD
Pre Star Time (s)	Control	43.92	11.50
	Experimental	42.41	16.29
Post Star Time (s)	Control	40.28	7.96
	Experimental	30.27*	6.96
Pre Star Errors	Control	2.33	1.87
	Experimental	3.64	2.06
Post Star Errors	Control	1.42	0.99
	Experimental	0.79	0.80

*Significant at the .0001 level

Bilateral Coordination Subtest of the Bruininks-Oseretsky Test of Motor Proficiency

A one-way MANCOVA was calculated examining the effect of cup stacking on the bilateral coordination subtest post-test scores of the Bruninks-Oseretsky Test of Motor Proficiency. No significant effect was found (*Lambda*(6,12) = 0.41, $p > .05$) between groups when the bilateral coordination subtest pre-test scores were used as a covariate on the post-test scores. Cup stacking had no effect on the bilateral coordination subtest of the Bruninks-Oseretsky Test of Motor Proficiency. Descriptive statistics for the subtests of the Bruinks-Oseretsky Test of Motor Proficiency are outlined in Table 2.

Upper Limb Coordination Subtest of the Bruininks-Oseretsky Test of Motor Proficiency

A one-way MANCOVA was calculated examining the effect of cup stacking on the upper limb coordination subtest post-test scores of the Bruninks-Oseretsky Test of Motor Proficiency. A significant effect was found (*Lambda*(6,12) = .359, $F = 3.57$, $p < .05$) between groups in the time to up stack when the upper limb coordination subtest pre-test scores were used as a covariate on the post-test scores. Follow up univariate ANOVAs indicated an interaction between the pre-test upper limb coordination subtest and the post-test time to up stack ($F(1,17) = 5.28$, $p < .05$). Descriptive statistics for the subtests of the Bruninks-Oseretsky Test of Motor Proficiency are outlined in Table 2.

Table 2

Descriptive Statistics for the Bruninks-Oseretsky Test of Motor Proficiency Subtests

		Mean	SD
Pre Bilateral Coordination Score	Control	14.25	2.98
	Experimental	13.14	1.65
Post Bilateral Coordination Score	Control	16.33	3.92
	Experimental	14.69	2.02
Pre Upper Limb Coordination Score	Control	19.5	0.79
	Experimental	19.14	1.09
Post Upper Limb Coordination Score	Control	19.58	1.44
	Experimental	18.69	1.18

Age adjusted norms for each of the subtests are reported in the Bruninks-Oseretsky Test of Motor Proficiency Manual (Bruninks, 1978). The norms published in the manual recorded the subtest standard scores of 19-23 to be in the upper nineteen percent of the norm group and describe the performance as above average. Scores of 12-18 are in the upper fifty-four percent and are described as average. The post-test bilateral coordination subtest standard scores are 19 for the experimental group and 20 for the control group. The post-test upper limb coordination standard scores are 16 for the experimental group and 19 for the control group. Standard scores for this study are reported in Table 3. Conversion of raw scores to standard scores is reported in Table 4 by the bold figures. Interpretations of standard scores are reported in Table 5.

Table 3

Post-test Norms for the Bruninks-Oseretsky Test of Motor Proficiency Subtests

			Description
Bilateral Coordination Subtest Standard Score	Control	20	above average
	Experimental	19	above average
Upper Limb Coordination Subtest Standard Score	Control	19	above average
	Experimental	16	average

Table 4

Standard Scores to Subtest Point Scores for the Bruninks-Oseretsky Test of Motor Proficiency

Subtest Standard Score	*Bilateral Coordination*	*Upper Limb Coordination*
36		
35		
34		
33		
32		
31		
30		
29		
28	**20 (Control)**	
27		
26	**19 (Experimental)**	
25		
24	18	
23		
22	17	21
21		
20	16	
19	15	**20 (Control)**
18		
17	14	
16		**19 (Experimental)**
15	13	
14		
13	12	18
12	11	
11		
10	10	17
9		
8	9	
7		16
6	8	
5	7	15
4		
3	6	14
2	5	13
1	0-4	0-12

Table 5

Interpretation of Standard Scores for the Bruninks-Oseretsky Test of Motor Proficiency

Subtest Standard Score	*Percent of Norm Group*	*Description of Performance*
Above 23	4	High
19-23	19	Above Average
12-18	54	Average
6-11	19	Below Average
Below 6	4	Low

Kinematics of Cup Stacking

A one-way MANCOVA was calculated examining the effect of cup stacking the cup clearance height. No significant effect was found (*Lambda*(6,12) = 0.71, $p > .05$) between groups in the cup clearance height post-test when using the cup clearance height pre-test as a covariate. Cup stacking had no effect on cup clearance height.

A one-way MANOVA was calculated examining the effect of cup stacking the up stack time. No significant effect was found (*Lambda*(6,12) = 0.73, $p > .05$) between groups in the up stack time post-test when using the up stack time pre-test as a covariate. Cup stacking had no effect on the up stack time. Descriptive statistics for the kinematics of cup stacking are outlined in Table 6.

Table 6

Descriptive Statistics for the Kinematics of Cup Stacking

		Mean	SD
Pre Cup Clearance Height (m)	Control	0.054	0.014
	Experimental	0.065	0.010
Post Cup Clearance Height (m)	Control	0.058	0.011
	Experimental	0.060	0.010
Pre Up Stack Time (s)	Control	4.35	1.15
	Experimental	3.73	1.09
Post Up Stack Time (s)	Control	3.13	0.61
	Experimental	2.23	0.54

Qualitative Data

Qualitative data were collected following this study. On a scale of 1-5, with one being the lowest and 5 being the highest, the experimental group rated their enjoyment of cup stacking a 4.15 (SD = 0.89). The majority (8 out of 12) participants in the experimental group indicated they were interested in continuing a cup stacking program in their physical education class. Descriptive data for the qualitative analysis are represented in Table 7.

Table 7

Qualitative Analysis of Student's Satisfaction

	Mean	SD
Rating of enjoyment Scale of 1-5 with 5 being the highest	4.153	0.898
Interested in continuing cup stacking in physical education class?	Yes = 8	N = 4

Summary

A one-way MANCOVA was run using the pre-tests as covariates. Univariate ANOVAs were used to determine significant differences once the multivariate test showed significance. Significant differences were found between the groups in the post-test tracer time. Significant differences were also found between the groups on the time to up stack when controlling for the pre-test upper limb coordination score.

CHAPTER V

Discussion

Cup stacking has become one of the fastest growing sports in America. Its use in over 6600 physical education programs and after school programs in the United States is an indication that there is interest in the sport. Some research has been conducted to measure the effects of feedback on a novel task of cup stacking in a physical education class (Fredenburg, Lee, & Solmon, 2001). Other research has been conducted to measure the psychomotor benefits to a cup stacking program (Conn, 2003; Hart, Smith, & DeChant, 2003; Udermann, Murray, Mayer, & Sagendorf, 2003). Although there is plenty of empirical evidence to support the inclusion of cup stacking in a physical education curriculum, only three previous studies have attempted to measure the benefits of cup stacking.

Speed Stacks, Inc., the leading manufacture of cups for the sport, claims that the sport of cup stacking has a positive effect on bilateral coordination. While other studies have attempted to measure hand-eye coordination, reaction time, and movement time changes with cup stacking, no studies have measured bilateral coordination changes. Therefore, the purpose of this study was to measure upper limb coordination changes using a five week cup stacking intervention. The specific aims of this study were to measure upper limb coordination changes with a star tracer task and two subtests of the Burininks-Oseretsky Test of Motor Proficiency, as well as to three dimensionally analyze the sport of cup stacking. We used the Peak Performance Motion Analysis System (Motus Ver. 7.3.2, Centennial, CO.) to measure cup clearance height and time to up stack.

Summary of Findings

A one-way MANCOVA was used to determine significant differences between the dependent variables using the pre-test scores as covariates. Once a multivariate test showed significant differences, separate univariate ANOVAs were used to determine differences between variables. All pre-test scores were used as a covariate for the post-test scores. The dependent variables examined for this study were post-test star tracer times, post-test star tracer errors, post-test bilateral coordination scores, post-test upper limb coordination scores, post-test up stack times, and post cup clearance heights. Alpha was set at .05 to test for statistical significance.

Two of the variables were found to be statistically significant. The time of the cup stacking group was found to be significantly lower than the control group in the star tracer time. In addition, the cup stacking group's time to up stack was found to be significantly shorter than the control group using the upper limb coordination subtest as a covariate for the cup stacking group.

Star Tracer

The star tracer is classified as a two-handed coordination test. This test involved manipulating a stylus around a star shape using both hands to control the apparatus. Both limbs must move in coordination together to complete the task as fast and as accurate as possible. Both time to complete the task and errors committed by moving the stylus off the star were recorded.

The results of this study indicated that the cup stacking group scored significantly better (m = 30.25s, sd = 6.69) on the post-test time when compared to the control group (m = 40.28s, sd = 7.96). Because the pre-test was used as a covariate, it can be concluded that better performance on this task was most likely due to the cup stacking intervention. Cup stacking requires that the participant repetitively use both limbs at the same time, a skill which is also required in the star tracer task.

The results of the analysis on error performance did not show significance. Although the experimental group was more accurate (m = 0.85 errors, sd = 0.8) than the control group (m = 1.42, sd = 0.99), it did not prove to be statistically significant. It can be concluded that cup stacking did not have an effect on accuracy as measured by errors in the star tracer test.

The star tracer is a task that gives the best indication of the effects of cup stacking on bilateral coordination. When asked if they had ever done a task similar to the star tracer, all of the participants answered no. This task was a measure of both two handed coordination speed and accuracy, and an overall measure of motor control. Our results indicated that the cup stacking group was able to control their upper limbs better than the control group following the five weeks of cup stacking. This indicates that cup stacking has a positive effect on bilateral coordination in our sample population of sixth graders. The ability to control both limbs at the same time is a variable that is used in many activities of daily living. Bilateral coordination is used to type on a keyboard, drive a car, and play an instrument. In addition, bilateral coordination is used in almost every aspect of sport and physical activities, such as dribbling a basketball with both hands, catching and throwing a baseball, and performing a cartwheel. A non-traditional sporting activity, such as cup stacking, could be included in training programs for better upper limb motor control. Also, rehabilitation programs could benefit from the implementation of a cup stacking program.

This study supports the findings of Udermann, Murray, Mayer, & Sagendorf (2003). They measured hand-eye coordination changes using the Soda Pop Test and reaction time changes using the Yardstick Test. These authors found that hand-eye coordination and reaction time improvements were shown following a five week cup stacking unit in the treatment group. The population (N = 42) consisted of two second grade physical education classes. This was the first study to show improvement in psychomotor variables using cup stacking as the treatment. However, the authors did not address if the control group also exhibited the same improvements.

This study does not support the work of Hart, Smith, and DeChant (2003). The researchers measured hand-eye coordination changes in first, third, and fourth grade physical education classes (N = 104). They used three separate measures of hand-eye coordination to quantify changes. The measures included: (a) placing pennies in a cup with both hands, (b) placing pennies in a cup with the non-dominate hand, and (c) placing pegs in a peg board. The researchers concluded that a three week unit in cup stacking did not elicit any changes in hand-eye coordination. They also suggested that a three week cup stacking unit may not be long enough to produce changes in hand-eye coordination. Although the tasks chosen by these researchers were novel tasks, they may not have been discriminatory enough to measure changes in hand-eye coordination. That is one of the reasons we chose to implement a different novel task, the star tracer, as one of our measures of two handed coordination. Also, our population of sixth graders was an older sample than the one used by Hart and colleagues. The older population may have developmentally allowed for the measured changes to occur in our allotted time.

Conn (2003) conducted a cup stacking study that measured psychomotor variables. She examined four fourth grade physical education classes (N = 82) for changes in movement time and reaction time and separated them into a control group and a treatment group. Her findings indicate that there were no significant differences between pre-test and post-test reaction time scores for either group. However, significant differences in movement time were found for the both of the groups. Our study, although not statistically significantly, indicated similar results. The time to up stack decreased in the experimental group, but not the control group. This indicates that the cup stacking group was completing the same movement faster due to the cup stacking intervention.

This study generally supports the findings of other research studies that investigated psychomotor variables using cup stacking as a treatment. Although this is only the fourth known study on cup stacking, three out of the four have found significant differences in psychomotor parameters due to a cup stacking program. This indicates that overall, research suggests that cup stacking has a positive influence on psychomotor parameters.

Bilateral Coordination Subtest of the Bruininks-Oseretsky Test of Motor Proficiency

The bilateral coordination subtest of the Briuninks-Oseretsky Test of Motor Proficiency for this study did not prove to be significant. This subtest included tasks such as tapping the opposite foot and finger, jumping up and clapping their hands as many times as they could, and drawing lines and crosses simultaneously. Although individual differences were seen in the tasks, the groups were not significantly different.

This could be due to the fact that a ceiling effect was found in this task. The ceiling effect, as defined by Schmidt and Lee (1999), is when the participant has reached the limit or near the limit for the task. This was the case for this test. Almost all of the performers scored near the top in all tasks for the pre-test. This left very little room for improvement during the post-test. Since the pre-test was used as a covariate, it was virtually impossible for the groups to become significantly better during the post-test.

Norms are reported for these subtests up to ages 14 ½ years old in the Bruininks-Oseretsky Test of Motor Proficiency Testing Manual (Bruininks, 1978). The average age of the participants for this study was 11.68. Although this is well within the age adjusted norm values reported in the manual, the participants nearly scored at the top of every category in the subtests. Almost all of the participants were able to jump in place with their arm and leg on the same side, jump up and clap their hands at least three times, and jump up and touch their heels. The tasks proved to be too easy for this sample population. It is recommended that this set of subtests not be used to discriminate between normal populations for this age group. Since the last set of norms was developed in 1978, the development of a new set of norms should be researched. Increases in size, strength, and nutrition of today's youth may prove that the norms of 25 years ago are no longer valid.

Upper Limb Coordination Subtest of the Bruininks-Oseretsky Test of Motor Proficiency

The upper limb coordination subtest of the Bruininks-Oseretsky Test of Motor Proficiency consisted of tasks such as catching a tossed ball with both hands, catching a tossed ball with the preferred hand, and bouncing a ball and catching it with the preferred hand. It did not prove to be significant when comparing groups using the pre-test of the upper limb coordination subtest as a covariate. However, when controlling for the upper limb coordination pre-test scores, the time to up stack showed a significant difference between groups.

The ceiling effect could again be the reason for no significant differences between groups for the upper limb coordination subtest of the Bruininks-Oseretsky Test of Motor Proficiency. Simple tasks such as catching a bounced ball with both hands and throwing a ball at a target with the preferred hand were much too easy for this population. The only task that proved difficult for the participants was touching a swinging ball with the preferred hand. Just as in the bilateral coordination subtest, the pre-test scores were used as a covariate. This made it difficult to see any changes as the pre-test scores were already high.

The only part of both of the subtests that was not rated above average by the subtest standard score was the upper limb coordination post-test for the cup stacking group. A norm adjusted score of 19 out of 21 proved to fall into the average range for this task. Although this is classified as average, the control group scored 20 out of 21 and fell into the above average description. See Tables 3, 4, and 5 for a visual description. Although the groups fall into different description categories, their scores were very similar.

Significance was found between groups in the time to up stack when controlling for the pre-test of the upper limb coordination score. Investigating the descriptive statistics, the upper limb coordination pre-test and post-test values were virtually the same while the post-test up stack time decreased. Upon further investigation, no connection could be found between the post-test scores of the upper limb coordination subtest and the time to up stack. We believe that the upper limb coordination subtest and the time to up stack are not related variables.

Kinematics of Cup Stacking

This was the first study to three dimensionally analyze the sport of cup stacking. The participants were asked to up stack a 6-6 stack in a controlled but timely manner. They completed the task three times and the best one of the three was analyzed. Markers were placed on their shoulder, elbow, wrist, and knuckle in order to create a multidimensional moving model. Elbow and wrist angles were analyzed in a pilot study to determine if angle-angle diagrams would sufficiently analyze a cup stacking motion. Also, a vector coding system of quantifying coordination was explored. It was found that the sport of cup stacking, specifically the up stack of the 6-6, created variable elbow and wrist angles. No repeatable patterns were found, so an attempt to quantify upper limb coordination using the angle-angle or vector coding system had to be dismissed.

Another way to measure efficient movement in cup stacking is to measure the vertical component of cup clearance. In biomechanical terms, the difference between the maximum Y value during each up stack to the minimum Y value when the cup is placed down indicated cup clearance height. See Figures 2-4 for a visual example. In Figure 2 the right knuckle has a Y value of 0.0645 meters before the first vertical motion of the up stack begins. In Figure 3, the peak of the vertical motion has occurred with the maximum right knuckle Y value being 0.0938 meters. In Figure 4, the right knuckle minimum Y value has occurred with the cup being placed back down and a Y value 0.0802 meters has been observed. The difference between the Y values at the peak (Figure 3) and the minimum (Figure 4) was defined as the cup clearance. This example would produce a cup clearance of 0.0136 meters. The 6-6 stack requires three upward movements to complete the stack. The average of the three cup clearances were used to determine the average cup clearance for each individual.

Figure 2. Starting position of up stack, right knuckle value of Y = 0.0645 meters

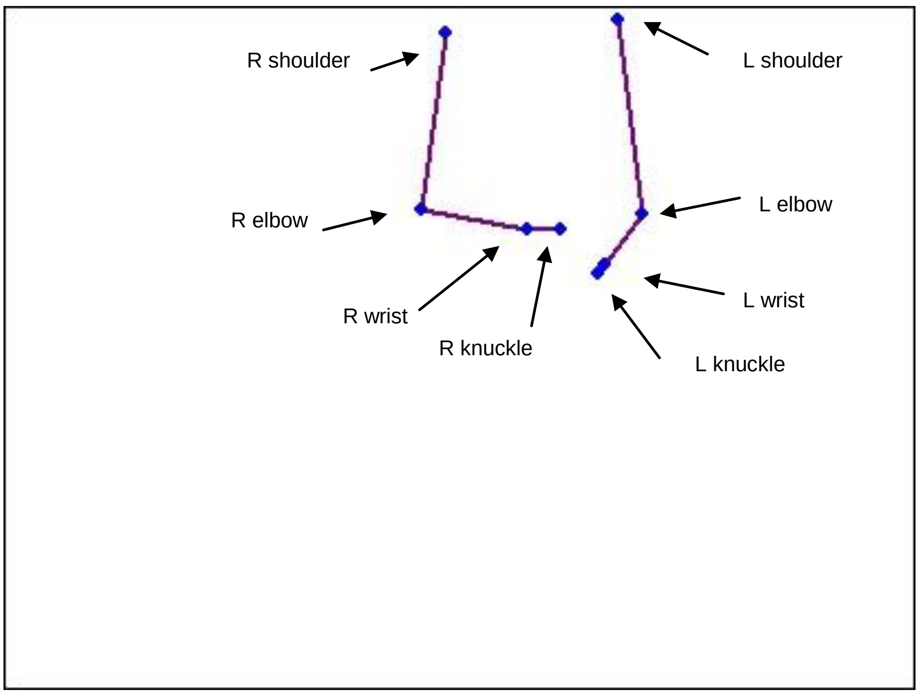


Figure 3. Peak positive vertical position of up stack, right knuckle value of Y = 0.0938 meters

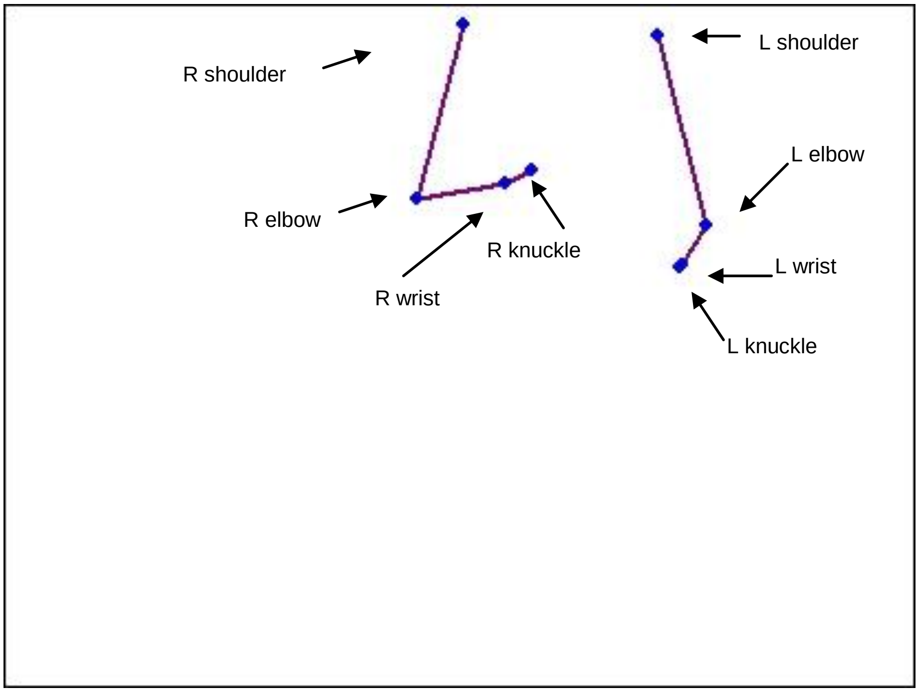
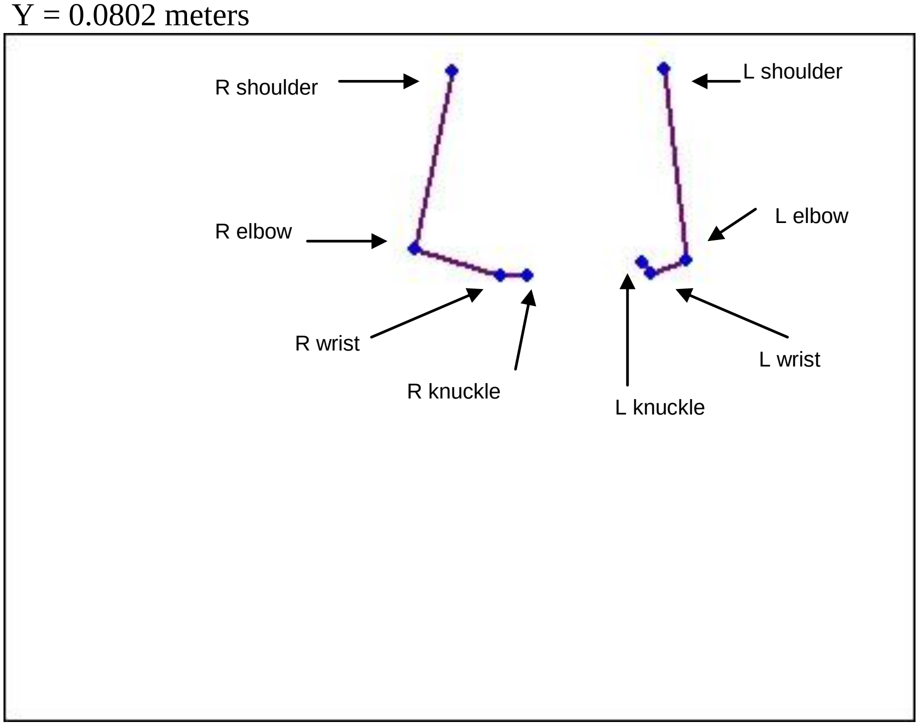


Figure 4: Peak negative vertical position of up stack, right knuckle value of Y = 0.0802 meters



The values of average cup clearance remained nearly the same from the pre-test to the post-test for both groups. This indicated that the participants did not move more efficiently during the post-test, regardless of the group they were in. This could be due to the fact that the cup stacking group only received cup stacking instruction and practice time for 15 minutes every other day. This means that they were cup stacking for 30 minutes one week and 45 minutes the next week, as they had physical education every other day. This may not have provided enough time to accurately learn the efficient movement pattern, since it was expected that an efficient movement pattern would have been a reduction in cup clearance height.

This supports the work of Hart, Smith, and Dechant (2003). They used a three week cup stacking unit as a treatment to measure changes in hand-eye coordination. Only one of the three hand-eye coordination tasks proved to be significantly different when comparing the pre-test to the post-test. The authors suggested that the length of instruction should be examined in future studies to see if three weeks is long enough to elicit changes.

Although we chose to implement cup stacking for five weeks rather than three weeks, the total time the participants had to stack cups was lower in our study. In the Hart, Smith, and Dechant (2003) study, the participants were from an elementary school that has daily physical education for 30 minutes each session. Their total time with cups was about twice as long as our study. Therefore, the question of appropriate cup stacking instruction and practice length remains unanswered.

Another measure of cup stacking efficient movement is the time it takes to up stack the 6-6 stack. This is defined as the time the first vertical movement in the cups occurs and ends when the sixth cup is placed on top of the 6-6 pyramid. A faster (smaller) time would indicate that the participant moved through space quicker and finished the task more rapidly.

Although the time decreased from pre-test to post-test, the time to up stack did not prove to be significant when using the pre-test as a covariate. This indicates that both groups finished the task quicker during the post-test. As stated in previous paragraphs, the average cup clearance did not change from pre-test to post-test. This indicates that the participants were able to follow the same movement, but at a quicker pace.

Time of instruction and practice could have affected the time to up stack post-tests as well. Our results indicate that the participants were moving somewhat more efficiently, as they were able to complete the task with a faster time during the post-test. Perhaps a longer period of instruction and practice would have allowed the participants to follow a more efficient path (lower cup clearance) while continuing to lower their up stack time. A lower cup clearance would mean that the performer is covering less space, thus decreasing the distance traveled. The combination of the two variables would create a faster cup stacker.

Qualitative Data

Qualitative data were collected to measure the enjoyment of participating in the cup stacking group. Two questions were asked. They were: "Are you interested in continuing cup stacking in your physical education class?" and "Rate you enjoyment of cup stacking on a scale of 1 to 5, with 1 being the lowest and 5 being the highest."

Most (8 out of 12) were interested in continuing cup stacking in their physical education class. This indicates that it was an enjoyable activity for the class. A physical education teacher that brings in something new to his/her class could provide motivation for participation in physical education. The ultimate goal of physical education is to promote active, healthy lifestyles. By bringing in new and innovative activities to the class, the physical educator may provide a more enjoyable atmosphere for all students to take pleasure in more physical activities. It appears that cup stacking is an enjoyable sport to support the goals of physical education.

On a rating scale of 1 to 5, with 1 being the lowest and 5 being the highest, the students rated their enjoyment of cup stacking at a 4.15 (*sd* = 0.89). This indicates that the students that participated in the cup stacking group rated the activity high. This is important in a motivation sense, as a student is more likely to participate in an activity that they enjoy.

The work of Fredenburg, Lee, and Solmon (2001) is the most similar to the qualitative data that we collected. Their research investigated the role of feedback during the novel task of cup stacking. The researchers provided different types of feedback during both the simple and complex movements of cup stacking. The researchers found no significant differences in feedback type in the simple movements of cup stacking. They did, however, find that feedback was important when learning the complex skills of cup stacking.

The link between their study and our study is that feedback was given in a positive, specific, corrective, and immediate manner during the entire five weeks of cup stacking in our study. This may have assisted the participants to learn the new movements, along with keeping their motivation high for the sport. The feedback may have been an indirect link to their enjoyment of cup stacking.

Conclusions

This study supported one of our hypotheses. A significant decrease in the star tracer time for the cup stacking group indicates better bilateral coordination. This suggests that cup stacking has a positive effect on bilateral coordination. This is a powerful statement, as bilateral coordination is a variable used in many sporting activities, such as dribbling in basketball, and many activities of daily living, such as driving a car.

This study did not support any of the other hypotheses. One other group of variables showed significance, time to up stack when controlling for the upper limb coordination pre-test. Upon further investigate, no correlation was found between the two variables. This indicates that the two variables are not related.

Qualitative data indicated that students who participated in the cup stacking group enjoyed the sport. This could be an important factor in motivation, something most teachers are always looking to raise in their students. Most of the students that participated in the cup stacking group indicated that they would like to continue a cup stacking program in their physical education class.

Recommendations for Future Studies

As suggested in previous research, the time of actual practice and instruction time needs to be investigated. Days of instruction, along with time of instruction each day should be studied in order to know how long it takes to elicit changes in hand-eye coordination, bilateral coordination, reaction time, and movement time.

A larger sample is usually needed to produce more power. We used one sixth grade class (N = 26) and the results supported one of our hypotheses. Several of the other investigated variables supported the direction of our additional hypotheses, but were not statistically significant. The observed power was between .55 and .68 indicating a larger sample may have given this study more power.

An investigation of a different age sample would allow us to better understand the development of motor control. This study indicated that cup stacking had a positive influence on the development of bilateral coordination in sixth grade physical education students. Our sample population was from a charter school in the southeastern United States, so our results can only be generalized with comparable populations. Similar studies should be performed with younger populations and varying demographical populations to determine if cup stacking has benefits at different levels.

Since we have shown that cup stacking has a positive effect on the development of bilateral coordination, an investigation in a rehabilitation setting would allow us to test a different population. Cup stacking may have a positive effect on the redevelopment of bilateral control. Also, a learning disability or mentally retarded population may benefit from the training of a cup stacking program.

Lastly, research should be undertaken to investigate cup stacking versus other activities that may promote upper limb coordination. A similar research design using juggling as the intervention may give researcher an indication of which activity promotes upper limb coordination faster. These types of investigations would allow teachers to better choose sporting activities to include in their curriculum based on sound research.

Teaching Implications

A five week intervention of cup stacking had a positive influence on bilateral coordination, as measured by a star tracer. Other variables measured did not prove to be significant, although reasons for nonsignificance have been presented. Qualitative research following this study indicated that most of the students that participated in the cup stacking unit enjoyed the sport and wanted to continue it in physical education class. This research project added supportive data to the literature for the inclusion of cup stacking in a physical education program. Although no conclusive evidence exists on the benefits of cup stacking, it appears that most students enjoy the activity. At a minimum, using the sport to promote enjoyment in physical education class may provide more students with the motivation to take pleasure in other healthy, active lifestyle activities.

Summary

The purpose of this study was to research the effects of cup stacking. We found that cup stacking has a positive effect on the development of bilateral coordination in sixth grade physical education students. This is a very powerful statement, as the development of bilateral coordination is something that everyone does throughout their life. Bilateral coordination is a variable that is used in activities of daily living as well as sporting activities. This study suggests that cup stacking can lead to better development of bilateral coordination.

Although none of the other tests proved to be significant, explanations have been explored for perhaps why this occurred. This study confirmed results of the previous studies that investigated cup stacking. This is the fourth study to suggest that cup stacking has a positive effect on psychomotor parameters. Future research suggestions have been made in order to further our understanding of the sport of cup stacking. More populations need to be investigated in order to more appropriately validate the inclusion of cup stacking in a physical education program.

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APPENDICES

Appendix A

Parent/Guardian Informed Consent Form

Barry University
Consent Form

Dear Guardian;

Your son/daughter's participation in a research project is requested. The research is being conducted by Chris Rhea, a graduate student in the Sport and Exercise Science Department at Barry University, and is seeking information that will be useful in the field of movement science. The aims of the research are to measure coordination changes following cup stacking instruction in their physical education class. Cup stacking is a new sport that is being taught in over 6600 physical education programs. The students up-stack and down-stack 12 specially designed cups in different pyramid forms. In accordance with these aims, the following procedure will be used: a pretest of three coordination changes will be measured prior to the study. This includes a two handed coordination task, two subtests that measure motor proficiency, and a 3-D analysis of upper limb movements in our biomechanics laboratory. We anticipate the number of participants to be 30.

If you decide to allow your son/daughter to participate in this research, they will be asked to participate in the three pretests and then be assigned to either an experimental or control group. The experimental group will receive cup stacking instruction for the first 15 minutes of their physical education class, while the control group will do fitness activities during the same time. They will be given the same coordination tests following three weeks of instruction, and again follow six weeks of instruction. Testing equipment includes: cup stacking cups, a two handed coordination task apparatus, inventories of the subtests from the Bruininks-Oseretsky Test of Motor Proficiency, and the Peak Performance Motion Analysis System 7.3.2 (Centennial, CO) for 3-D analysis.

On your son/daughter's first day of the research project, they will be given the first two coordination tests, the two handed coordination test, and the two subtests. Their second day of the research project will consist of receiving the first lesson in cup stacking. Following this lesson, they will be videotaped in our biomechanics laboratory using four cameras for 3-D analysis. They will have four retroreflective markers placed on each side of their upper body with athletic tape. The placement includes the: 1) shoulder, 2) elbow, 3) wrist, and 4) knuckle. The following three weeks of physical education class will start with the control group doing fitness activities and the experimental group doing cup stacking activities for the first 15 minutes of class. The rest of the physical education time will be spent doing regularly planned physical activities.

Your consent to allow your son/daughter to be a research participant is strictly voluntary and should you decline to allow them to participate or pull them out of the study at any time during the study, there will be no adverse effects on their academic standing.

The risks of involvement in this study include increased anxiety and increased heart rate. The risks will be reduced by teaching your student that racing in cup stacking is not the goal of the activity. They will be told that self-improvement is the main objective for this study. The benefit to your son/daughter is the opportunity to see if cup stacking positively effects coordination changes. Increasing coordination could help in everyday activities, along with sporting activities.

As a research participant, information your son/daughter provides will be held in confidence to the extent permitted by law. Any published results of the research will refer to group averages only and no names will be used in the study. Data will be kept in a locked file in the researcher's office. Data will be destroyed seven years after collection. No names will be used during the analyzing phase of the study. The analyzed trials will only use a letter and number designation. Your signed consent form will be kept separate from the data.

If you have any questions or concerns regarding the study or your son/daughter's participation in the study, you may contact Chris Rhea at (305) 984-5367, my supervisor, Dr. Ludwig, at (305) 899-4077, or the IRB point of contact, Ms. Avril Brenner, at (305) 899-3020. If you are satisfied with the information provided and are willing to allow your son/daughter to participate in this research, please signify your consent by signing this consent form.

Voluntary Consent

I acknowledge that I have been informed of the nature and purposes of this experiment by Chris Rhea and that I have read and understand the information presented above, and that I have received a copy of this form for my records. I give my voluntary consent to allow my son/ daughter to participate in this experiment.

______________________ __________

Signature of Guardian *Date*

______________________ __________

Researcher *Date*

Appendix B

Participant Assent Form

Barry University

ASSENT FORM INVOLVING MINORS

We are doing a research study that includes children such as you. We have explained the study to you, and we need to know whether you are willing to participate. Please sign your name below so that we can be certain whether you want to be in the study or not. Thank you.

____ I am willing

____ I am not willing

to participate in the research study which has been explained to me by Chris Rhea.

______________________________________ ____________________

Signature of Researcher *Date*

______________________________________ ____________________

Signature of Child *Date*

______________________________________ ____________________

Signature of Parent *Date*

Appendix C

Lesson Plans

Cup Stacking Lesson Plan

Day one of the Unit
6-6 Stack

Date/Class Period: Monday, February 16th/ 6th Grade Physical Education

Equipment Needed: Cup stacking video, TV/VCR, 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student. The teacher will be playing a video as the students enter the classroom, so that the students gain interest immediately.

Performance Objectives: Psychomotor-The student will be able to execute a 6-6 stack properly three times in a row.

Affective-The student will assist other classmates that are having problems performing a 6-6 stack.

Cognitive-The student will be able to describe the key components of a 6-6 stack

Instructional Input/Modeling:

a. Up stacking is a term used when you are stacking the cups up. Gently grip the cup with your hand in the shape of a "C", keeping your pinky finger underneath the cup. Grab the cup from the side.

b. Down stacking is the term used when you are taking the cups down from their up stacked position.

c. Fumble is a term used when the cups fall during the stacking phase. If a fumble occurs in the up stacking phase the stacker must stop stacking and correct the fumble

d. You must start with both hands flat on the table. Stack from left to right and keep the cups close together to avoid fumbles.

6-6 upstack

a. With the right hand pick up three cups.

b. With the left hand, pick up two cups leaving one cup on the table

c. Place the bottom cup in your right hand on the right side of the cup on table

d. Place the bottom cup in your left hand on the left side of the cup on the table

e. Place the bottom cup in your right hand on top of the two cups on your right side

f. Place the last cup in your left hand on top of the two cups on your left side

g. Place the final cup in your right hand on top of the pyramid

6-6 downstack

a. Place your right hand on the top cup

b. Place your left hand on the next highest cup on the left side

c. Slide your right hand down the right side of the pyramid, capturing three cups

d. Slide your left hand down the left side of the pyramid, capturing two cups

e. Pick up the two cups on your left side and slide it over the middle cup, ending in a 3-3 stack

Error: Grabbing too many cups
Correction: Use pinky finger to control the cups
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to practice the 6-6 stack. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the difference between the up stack and a down stack is. Also, how do you make an up stack and down stack.

Cup Stacking Lesson Plan

Day two of the Unit

3-3 Stack

Date/Class Period: Wednesday, February 18th/ 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: <u>Psychomotor</u>-The student will be able to execute a 3-3 stack properly three times in a row.

<u>Affective</u>-The student will assist other classmates that are having problems performing a 3-3 stack.

<u>Cognitive</u>-The student will be able to describe the key components of a 3-3 stack

Instructional Input/Modeling:

3-3 upstack

a. With the right hand pick up one cup.

b. With the left hand, pick up one cup.

c. With the right hand, place the cup to the right of the cup on the table.

d. With the left hand, place the cup on top of the two cups on the table to create a 3 cup pyramid

e. Follow the same pattern with the next three cups

3-3 downstack

a. Place your right hand on the top cup

b. Place your left hand on the cup on the left side

c. Slide your right hand down the right side of the pyramid, capturing two cups

d. With your left hand take the left cup and put it on top of the other two cups

e. Follow the same pattern with the next three cups

Error: Starting with the left hand
Correction: Start with the right hand
Error: Moving from right to left
Correction: Start from the right and move to the left

Guided/Independent Practice: The students will have 15 minutes to practice the 3-3 stack. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the difference between the up stack and a down stack in the 3-3 stack is. Also, how do you make an up stack and down stack in the 3-3 stack.

Cup Stacking Lesson Plan

Day three of the Unit
3-3, 6-6 stack

Date/Class Period: Friday, February 20th/ 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: Psychomotor-The student will be able to execute a 3-3 and 6-6 stack properly three times in a row.

Affective-The student will assist other classmates that are having problems performing a 3-3 and 6-6 stack.

Cognitive-The student will be able to describe the key components of a 3-3 and 6-6 stack

Instructional Input/Modeling:

3-3 upstack

a. With the right hand pick up one cup.

b. With the left hand, pick up one cup.

c. With the right hand, place the cup to the right of the cup on the table.

d. With the left hand, place the cup on top of the two cups on the table to create a 3 cup pyramid

e. Follow the same pattern with the next three cups

3-3 downstack

a. Place your right hand on the top cup

b. Place your left hand on the cup on the left side

c. Slide your right hand down the right side of the pyramid, capturing two cups

d. With your left hand take the left cup and put it on top of the other two cups

e. Follow the same pattern with the next three cups

6-6 upstack

a. With the right hand pick up three cups.

b. With the left hand, pick up two cups leaving one cup on the table

c. Place the bottom cup in your right hand on the right side of the cup on table

d. Place the bottom cup in your left hand on the left side of the cup on the table

e. Place the bottom cup in your right hand on top of the two cups on your right side

f. Place the last cup in your left hand on top of the two cups on your left side

g. Place the final cup in your right hand on top of the pyramid

6-6 downstack

a. Place your right hand on the top cup

b. Place your left hand on the next highest cup on the left side

c. Slide your right hand down the right side of the pyramid, capturing three cups

d. Slide your left hand down the left side of the pyramid, capturing two cups

e. Pick up the two cups on your left side and slide it over the middle cup, ending in a 3-3 stack

Error: Grabbing too many cups
Correction: Use pinky finger to control the cups
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to practice the 3-3 and 6-6 stack. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the difference between the up stack and a down stack in the 3-3 and 6-6 stack is. Also, how do you make an up stack and down stack in the 3-3 and 6-6 stack.

Cup Stacking Lesson Plan

Day four of the Unit
3-6-3 Stack

Date/Class Period: Tuesday, February 24th/ 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: Psychomotor-The student will be able to execute a 3-6-3 stack properly three times in a row.

Affective-The student will assist other classmates that are having problems performing a 3-6-3 stack.

Cognitive-The student will be able to describe the key components of a 3-6-3 stack

Instructional Input/Modeling:

3-6-3 upstack

a. With the right hand pick up one cup.

b. With the left hand, pick up one cup.

c. With the right hand, place the cup to the right of the cup on the table.

d. With the left hand, place the cup on top of the two cups on the table to create a 3 cup pyramid

e. Move to the set of six cups

f. With the right hand pick up three cups.

g. With the left hand, pick up two cups leaving one cup on the table

h. Place the bottom cup in your right hand on the right side of the cup on table

i. Place the bottom cup in your left hand on the left side of the cup on the table

j. Place the bottom cup in your right hand on top of the two cups on your right side

k. Place the last cup in your left hand on top of the two cups on your left side

l. Place the final cup in your right hand on top of the pyramid

m. Move to the last set of three cups

n. With the right hand pick up one cup.

o. With the left hand, pick up one cup.

p. With the right hand, place the cup to the right of the cup on the table.

q. With the left hand, place the cup on top of the two cups on the table to create a 3 cup pyramid

3-6-3 downstack

a. Starting on the left hand side, place your right hand on the top cup

b. Place your left hand on the cup on the left side

c. Slide your right hand down the right side of the pyramid, capturing two cups

d. With your left hand take the left cup and put it on top of the other two cups

e. Move to the 6 stack

f. Place your right hand on the top cup

g. Place your left hand on the next highest cup on the left side

h. Slide your right hand down the right side of the pyramid, capturing three cups

i. Slide your left hand down the left side of the pyramid, capturing two cups

j. Pick up the two cups on your left side and slide it over the middle cup, ending in a 3-3 stack

k. Move to the 3 stack

l. Place your right hand on the top cup

m. Place your left hand on the cup on the left side

n. Slide your right hand down the right side of the pyramid, capturing two cups

o. With your left hand take the left cup and put it on top of the other two cups

Error: Grabbing too many cups
Correction: Use pinky finger to control the cups
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to practice the 3-6-3 stack. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the difference between the up stack and a down stack in the 3-6-3 is. Also, how do you make an up stack and down stack in the 3-6-3 stack.

Cup Stacking Lesson Plan

Day five of the Unit
Cycle Stack

Date/Class Period: Thursday, February 26th/ 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: <u>Psychomotor</u>-The student will be able to execute a cycle stack properly three times in a row.

<u>Affective</u>-The student will assist other classmates that are having problems performing a cycle stack.

<u>Cognitive</u>-The student will be able to describe the key components of a cycle stack

Instructional Input/Modeling:

Cycle Stack (3-6-3, 6-6, 1-10-1 stacks)

a. Follow same pattern for the 3-6-3

b. After down stacking the last 3 stack, bring it over to the left side with the other 3 stack

c. Start the 6 stack the same way as before and then move to the other 6 stack

d. After down stacking the both of the 6 stacks just as before, put all of the cups on top of each other with the right hand

e. Take one cup off the top with each hand and place them on the outside of the stacking space with one facing up and one facing down

f. Grab five cups with the right hand and four cups with the left hand

g. Place the bottom cup from the right hand on the right side of the cup left on the table

h. Place the bottom cup form the left hand on the left side of the cup left on the table

i. Again, place the bottom cup from the right hand on the right side of the cups

j. Place the bottom cup from the left hand in the middle of the second row of cups

k. Place the bottom cup from the right hand on the right side of that cup

l. Place the bottom cup from the left hand on the left side of the second row

m. Place the bottom cup from the right hand on the right side of the third row

n. Place the bottom cup from the left hand on the left side of the third row

o. Place the last cup in the right hand on the top completing the 10 cup pyramid

Error: Grabbing too many cups
Correction: Use pinky finger to control the cups
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to practice the cycle stack. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the difference between the up stack and a down stack in the cycle stack is. Also, how do you make an up stack and down stack in the cycle stack.

Cup Stacking Lesson Plan
Day six of the Unit
Cycle Stack (day 2)

Date/Class Period: Monday, March 1st / 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: Psychomotor-The student will be able to execute a cycle stack properly three times in a row.

Affective-The student will assist other classmates that are having problems performing a cycle stack.

Cognitive-The student will be able to describe the key components of a cycle stack

Instructional Input/Modeling:

Cycle Stack (3-6-3, 6-6, 1-10-1 stacks)

a. Follow same pattern for the 3-6-3

b. After down stacking the last 3 stack, bring it over to the left side with the other 3 stack

c. Start the 6 stack the same way as before and then move to the other 6 stack

d. After down stacking the both of the 6 stacks just as before, put all of the cups on top of each other with the right hand

e. Take one cup off the top with each hand and place them on the outside of the stacking space with one facing up and one facing down

f. Grab five cups with the right hand and four cups with the left hand

g. Place the bottom cup from the right hand on the right side of the cup left on the table

h. Place the bottom cup form the left hand on the left side of the cup left on the table

i. Again, place the bottom cup from the right hand on the right side of the cups

j. Place the bottom cup from the left hand in the middle of the second row of cups

k. Place the bottom cup from the right hand on the right side of that cup

l. Place the bottom cup from the left hand on the left side of the second row

m. Place the bottom cup from the right hand on the right side of the third row

n. Place the bottom cup from the left hand on the left side of the third row

o. Place the last cup in the right hand on the top completing the 10 cup pyramid

Error: Grabbing too many cups
Correction: Use pinky finger to control the cups
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to practice the cycle stack. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the difference between the up stack and a down stack in the cycle stack is. Also, how do you make an up stack and down stack in the cycle stack.

Cup Stacking Lesson Plan

Day seven of the Unit

Cycle Stack (Day 3)

Date/Class Period: Wednesday, March 3rd / 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: Psychomotor-The student will be able to execute a cycle stack properly three times in a row.

Affective-The student will assist other classmates that are having problems performing a cycle stack.

Cognitive-The student will be able to describe the key components of a cycle stack

Instructional Input/Modeling:

Cycle Stack (3-6-3, 6-6, 1-10-1 stacks)

a. Follow same pattern for the 3-6-3

b. After down stacking the last 3 stack, bring it over to the left side with the other 3 stack

c. Start the 6 stack the same way as before and then move to the other 6 stack

d. After down stacking the both of the 6 stacks just as before, put all of the cups on top of each other with the right hand

e. Take one cup off the top with each hand and place them on the outside of the stacking space with one facing up and one facing down

f. Grab five cups with the right hand and four cups with the left hand

g. Place the bottom cup from the right hand on the right side of the cup left on the table

h. Place the bottom cup form the left hand on the left side of the cup left on the table

i. Again, place the bottom cup from the right hand on the right side of the cups

j. Place the bottom cup from the left hand in the middle of the second row of cups

k. Place the bottom cup from the right hand on the right side of that cup

l. Place the bottom cup from the left hand on the left side of the second row

m. Place the bottom cup from the right hand on the right side of the third row

n. Place the bottom cup from the left hand on the left side of the third row

o. Place the last cup in the right hand on the top completing the 10 cup pyramid

Error: Grabbing too many cups
Correction: Use pinky finger to control the cups
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to practice the cycle stack. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the difference between the up stack and a down stack in the cycle stack is. Also, how do you make an up stack and down stack in the cycle stack.

Cup Stacking Lesson Plan

Day eight of the Unit
6-6 Partner Races

Date/Class Period: Friday, March 5th / 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: Psychomotor-The student will be able to complete the 6-6 partner races quickly.

Affective-The student will assist other classmates that are having problems performing a 6-6 stack.

Cognitive-The student will be able to describe the key components of a 6-6 stack

Instructional Input/Modeling:

6-6 Partner Races

a. With a partner, race a 6-6 stack through three times and see who wins

b. You may challenge a partner three times and then you much switch partners

c. Your goal is to challenge everyone in the class

Error: Creating too many fumbles
Correction: Moving too fast, slow down
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to challenge partners in the 6-6 partner challenge. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the made a successful challenge and what caused problems. I will lead the students to realize that moving as fast as you can isn't always the best way to perform an activity.

Cup Stacking Lesson Plan

Day nine of the Unit
3-6-3, 6-6 Partner Races

Date/Class Period: Tuesday, March 9th / 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: Psychomotor-The student will be able to complete the 3-6-3, 6-6 partner races quickly.

Affective-The student will assist other classmates that are having problems performing a 3-6-3, 6-6 stack.

Cognitive-The student will be able to describe the key components of a 3-6-3, 6-6 stack

Instructional Input/Modeling:

3-6-3, 6-6 Partner Races

a. With a partner, race a 3-6-3 and 6-6 stack through three times and see who wins

b. You may challenge a partner three times and then you much switch partners

c. Your goal is to challenge everyone in the class

Error: Creating too many fumbles
Correction: Moving too fast, slow down
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to challenge partners in the 3-6-3, 6-6 partner challenge. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the made a successful challenge and what caused problems. I will lead the students to realize that moving as fast as you can isn't always the best way to perform an activity.

Cup Stacking Lesson Plan

Day ten of the Unit

6-6 Team Races

Date/Class Period: Thursday, March 11th / 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: <u>Psychomotor</u>-The student will be able to complete the 6-6 team races quickly.

<u>Affective</u>-The student will assist other classmates that are having problems performing a 6-6 stack.

<u>Cognitive</u>-The student will be able to describe the key components of a 6-6 stack

Instructional Input/Modeling:

6-6 Team Races

a. With a team of three, record each teammates best of three 6-6 stack times on the timer mat

b. Add up the time for the team

c. The team that has the lowest combined time wins

Error: Creating too many fumbles
Correction: Moving too fast, slow down
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to challenge partners in the 6-6 team race. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the made a successful team race and what caused problems. I will lead the students to realize that moving as fast as you can isn't always the best way to perform an activity.

Cup Stacking Lesson Plan

Day eleven of the Unit

Cycle Stack Team Races

Date/Class Period: Monday, March 15th / 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: Psychomotor-The student will be able to complete the cycle stack team races quickly.

Affective-The student will assist other classmates that are having problems performing a cycle stack.

Cognitive-The student will be able to describe the key components of a cycle stack

Instructional Input/Modeling:

Cycle Stack Team Races

a. With a team of three, record each teammates best of three cycle stack times on the timer mat

b. Add up the time for the team

c. The team that has the lowest combined time wins

Error: Creating too many fumbles
Correction: Moving too fast, slow down
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to challenge partners in the cycle stack team race. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the made a successful team race and what caused problems. I will lead the students to realize that moving as fast as you can isn't always the best way to perform an activity.

Cup Stacking Lesson Plan
Day twelve of the Unit
Cycle Stack Team Races (Day 2)

Date/Class Period: Wednesday, March 17th / 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: Psychomotor-The student will be able to complete the cycle stack team races quickly.

Affective-The student will assist other classmates that are having problems performing a cycle stack.

Cognitive-The student will be able to describe the key components of a cycle stack

Instructional Input/Modeling:

Cycle Stack Team Races

a. With a team of three, record each teammates best of three cycle stack times on the timer mat

b. Add up the time for the team

c. The team that has the lowest combined time wins

Error: Creating too many fumbles
Correction: Moving too fast, slow down
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to challenge partners in the cycle stack team race. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the made a successful team race and what caused problems. I will lead the students to realize that moving as fast as you can isn't always the best way to perform an activity.

Cup Stacking Lesson Plan
Day thirteen of the Unit
Cycle Stack Team Races (Day 3)

Date/Class Period: Friday, March 19th / 6th Grade Physical Education

Equipment Needed: 12 cups for every student

Safety Factors: Students should be aware of one another so that they do not interfere with another person who may be practicing. Cups should **not** be slammed down on the table.

Anticipatory Set: The classroom will be set up and ready to go with enough sets of cups (12 cups to a set) for every student.

Performance Objectives: <u>Psychomotor</u>-The student will be able to complete the cycle stack team races quickly.

<u>Affective</u>-The student will assist other classmates that are having problems performing a cycle stack.

<u>Cognitive</u>-The student will be able to describe the key components of a cycle stack

Instructional Input/Modeling:

Cycle Stack Team Races

a. With a team of three, record each teammates best of three cycle stack times on the timer mat

b. Add up the time for the team

c. The team that has the lowest combined time wins

Error: Creating too many fumbles
Correction: Moving too fast, slow down
Error: Cup keep falling over (fumble)
Correction: Keep cups close enough when creating the stack

Guided/Independent Practice: The students will have 15 minutes to challenge partners in the cycle stack team race. I will walk around to give individual attention to those who need it.

Closure: Everyone returns their cups. I will ask what the made a successful team race and what caused problems. I will lead the students to realize that moving as fast as you can isn't always the best way to perform an activity.

Appendix D

BOTMP Scoring Sheet

Appendix E

Qualitative Questionnaire

Name ________________________

Age ________________

Gender MALE FEMALE

Did you participate in the cup stacking group for the last 5 weeks? YES NO

If yes, please answer below

Have you ever practiced with cup stacking before this study? YES NO

Have you ever seen cup stacking before this study? YES NO

Are you interested in continuing cup stacking in PE? YES NO

Please rate you enjoyment of cup stacking below

1	2	3	4	5
Low		Medium		High

Name ________________________

Age ________________

Gender MALE FEMALE

Did you participate in the cup stacking group for the last 5 weeks? YES NO

If yes, please answer below

Have you ever practiced with cup stacking before this study? YES NO

Have you ever seen cup stacking before this study? YES NO

Are you interested in continuing cup stacking in PE? YES NO

Please rate you enjoyment of cup stacking below

1	2	3	4	5
Low		Medium		High