THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF KINESIOLOGY

ADOLESCENT CLUMSINESS AND THE HAPTIC PERCEPTUAL SYSTEM

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for a baccalaureate degree
in Kinesiology
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Reviewed and approved* by the following:

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Abstract

Background: Adolescents often are described as clumsy and awkward. The emergence of clumsiness at the most rapid growth period is possibly due to a perceptual deficit. The perceptual system provides information about joint angles, muscle length, and muscle tension and without appropriate scaling the individual cannot veridically discern the world around them. ***Purpose:*** The purpose of the proposed research was to examine the effects of skeletal peak height velocity on the rapidly growing adolescent's motor control. It was hypothesized that the adolescents with the most rapid growth either skeletally or in Body Mass Index (BMI) were more likely to have a poor sense of where their body is in space versus those adolescents whose velocity of growth was the slowest. ***Methods*****:** All subjects (girls between the ages 9.5 to 10.5 years old) wielded objects in one hand behind a curtain and used the other to estimate the length of the rod used (Solomon and Turvey, 1989). 8 different length rods were tested 6 times each. A 5-question survey as well as height, weight and BMI were measured and calculated as well. ***Results*****:** Significant findings showed that as the length of the rod increased average error of the estimated rods increased as well. The results also showed that BMI was insignificant compared to the average error of estimated rod lengths. ***Conclusion*****:** The identified knowledge is a stepping-stone to further research about adolescent clumsiness and the lag in neural proprioception growth. Understanding adolescent clumsiness is critical for injury prevention and overall knowledge of developmental motor control.

Table of Contents

ACKNOWLEDGEMENTS

I would like to thank the subjects who volunteered their time for this study and for their cooperation. I would also like to thank Dr. Newell, Tim Benner and the motor control lab for helping me to construct and carry out my study properly.

Thank you!

Adolescent Clumsiness and the Haptic Perceptual System

Introduction

Adolescents often are described as clumsy and awkward (Malina, 2004). Reflecting on one's own pubescent time may trigger memories of confusion and embarrassment in the aggressive changes occurring in the body. Growing accustomed to this rapid transformation of body size and shape is difficult and seemingly takes forever. Wardrobe changes rapidly, exercise/sport modifications and of course the inevitable social aspects of the pubescent era begin to unfold. The root of the confusion, awkwardness, clumsiness, and embarrassment all emerge due to this rapid growth period is possibly due to a perceptual deficit or a lag in the neural growth and control of newly existing areas on the body (Quatman-Yates et al., 2011).

Clumsiness or decreased motor coordination has been a long-standing question for children and adolescents (Losse et al. 1991). There is a correlation showing that an increased risk of injury is often a concern for this age group (Quatman-Yates et al., 2011). During the adolescent growth stages at least some aspects of sensorimotor function are developing and certain sensorimotor functions/mechanisms may regress during puberty (Quatman-Yates et al., 2011). Due to this lag and possible regression in neural/perceptual growth, adolescents are labeled as clumsy or even awkward.

The perceptual system provides information about joint angles, muscle length, and muscle tension and without appropriate scaling; the body cannot appropriately discern the world around them (Duzgun et al., 2011). From information that is processed

through the body by a variety of stimuli, the body understands where and how to move or perceive it's surroundings (Duzgun et al., 2011). The purpose of this study is to examine the effects of the upward slope to skeletal peak height velocity on the rapidly growing adolescent's motor control. That is, the adolescents with the most rapid growth either skeletally or in Body Mass Index (BMI) will be more likely to have a poor sense of where their body is in space versus those adolescents whose velocity of growth is the slowest. According to a study by Philippaerts et al. (2006) peak development of balance, speed of limb movement, trunk strength, upper-body muscular endurance, explosive strength, running speed and agility, cardiorespiratory endurance and anaerobic capacity occurs at the same time as peak height velocity. Therefore, testing the upward rate of growth slope towards peak height velocity may yield interesting answers as to the perceptual development at that time, specifically proprioception.

BMI is a profound confounding variable in the sense that those who grow at a faster rate (vertically and/or horizontally) are at a greater perceptual disadvantage. The BMI index is calculated using a ratio of the child's weight to his/her height squared (CDC, 2011). BMI is normally used as a screening tool to help identify problems in weight and the likelihood of becoming over or underweight as well as advancing health changes later in life such as cardiovascular disease. BMI is not a diagnostic tool nor is it an exact gage of a child's body fat mass, but it is a reliable source of comparable information. Simply calculated body mass index is a correlate to direct measures of body fat testing like underwater weighing, dual energy x-ray absorptiometry (DEXA), bod pods, or even skin fold testing (Duren et al., 2008).

Haptic perception is the process by which the body distinguishes objects based on touch involving the somatosensory perception (feelings edges, textures and surfaces) and proprioception (knowing the hand position and conformation on the object) (Turvey, 1996). In order to narrow down the field of study the subjects (girls between the ages 9.5 to 10.5 years old) were asked to wield objects in one hand behind a curtain and use the other to estimate the length of the rod used. There were eight different rod lengths all created from aluminum metal. The rotational forces created while wielding the rod by lifting and turning, provide information to the body to judge the objects' size (Solomon, 1988). Therefore, the sensitivity that a person has to the rotational moment of inertia is used to determine the unseen length of an object, in this case, a rod. Because moments of inertia change with growth, the changes in growth height between 9.5 to 10.5 year olds may have an effect on their capacity to estimate rod lengths (Jensen, 1986). In a study on upper limb proprioceptive accuracy, subjects between 8-10 years old made larger proprioceptive perceptual errors than older adolescents between 16-18 years old (Goble et al., 2005).

Age is also a significant underlying factor in haptic perception. The peak height growth velocity is the highest rate at which growth takes place in a young person's life (Appendix C, Tanner et al. 1985). The highest rates occur in toddlerhood while the second peak is seen in adolescence. For girls the average ascent begins around 9 years old and peaks around 11.5 years old. This study takes a closer look at the rapid ascent of the average American girl. According to Jensen (1981), rotational movements, like the wielding that occurs in this study, are especially difficult during the extreme changes that occur during the peak height growth velocity in adolescence.

Methods

Participants:

Participants in this study were girls between ages 9.5 to 10.5 years old from the State College, Pennsylvania area. The participants were screened over the phone and divided into two groups: One group of girls who have a body mass index less than 45% and another group of girls who have a body mass index 85% and above.

All of the participants had no experience in the rod wielding tasks. Each participant and her respective guardian completed The Pennsylvania State University's approved Institute Review Board informed consent procedures. The subjects were paid $15 for completing the experiment.

Apparatus:

An apparatus similar to that used in Solomon, Turvey and Burton's (1989) study on haptics was used in this experiment. A chair was placed parallel to a curtain where the subject will be seated (Appendix D). The arm closest to the curtain was placed out of sight. The subject placed her forearm and wrist lined up with the edge of the armrest of the chair. Following this placement the end of the rod was placed in the palm of the subject's hand. Solomon, Turvey and Burton (1989) manipulated the rotational inertia by changing the hand position of the rod, but this study focused on one hand position in order to control the results of the study and to focus on one area of movement and perceptual information. 8 rods were each tested 6 times randomly for a total of 48 trials per individual. The rods used ranged from 30.5 cm to 142.4 cm in length.

Procedures:

The subject's task was to haptically determine the length of the rod. Participants sat in the chair placing one arm on the opposite side of the curtain so that the hand was out of sight. A rod was placed in the subject's hand. The subject estimated the length of the rod using proprioception by wielding the rod in any way and for as long as she needed to be comfortable to determine a reasonable length estimate. The subject left the forearm on the armrest of the chair, maintaining a singular handhold on the rod and simultaneously tried not to hit the curtain with the rod or let it touch the ground. After the subject was satisfied with her wielding, she then moved the platform to create a gap thought to be similar to the length of the rod (measuring from the wrist, which was placed at the edge of the armrest, to the board in front of the subject).

Before the subjects took a seat, the experimenter explained the process of the study and demonstrated how the apparatus operates. The subject was not allowed any practice time prior to the actual tests.

Also prior to the testing, the subject answered a five-question survey. The first question asked about shoes and foot growth. A study by Busscher et al. (2011) determined that shoe size changes are notable markers for predicting the timing of pubertal growth. The second question asked whether or not the subject had grown out of clothes, if the clothes were tighter than they used to be and when was the last time they bought/received new clothes. The third and fourth question asked how many times in the last 5 days the subject had tripped over an object and bumped in an object, respectively. The fifth question asked the subject if when she sees an object does she think the weight of the object will be heavier, lighter or exactly the same as the actual weight. After the

subject concluded answering the survey questions, height and weight measurements were taken using a doctor's scale in the lab in order to calculate body mass index (BMI).

Results

Inconsistent with the original intent of the study, 5 girls were below the 45th BMI percentile (2%, 3%, 19%, 31%, 35%), but no girls were above the 85th BMI percentile. The other 5 girls were between the 52nd and the 82nd percentile for BMI at their specific age (52%, 58%, 58%, 79%, 82%). Figure 1 shows that there is no statistical significance or difference between the Average Rod Length Error vs. BMI Percentage of each subject.

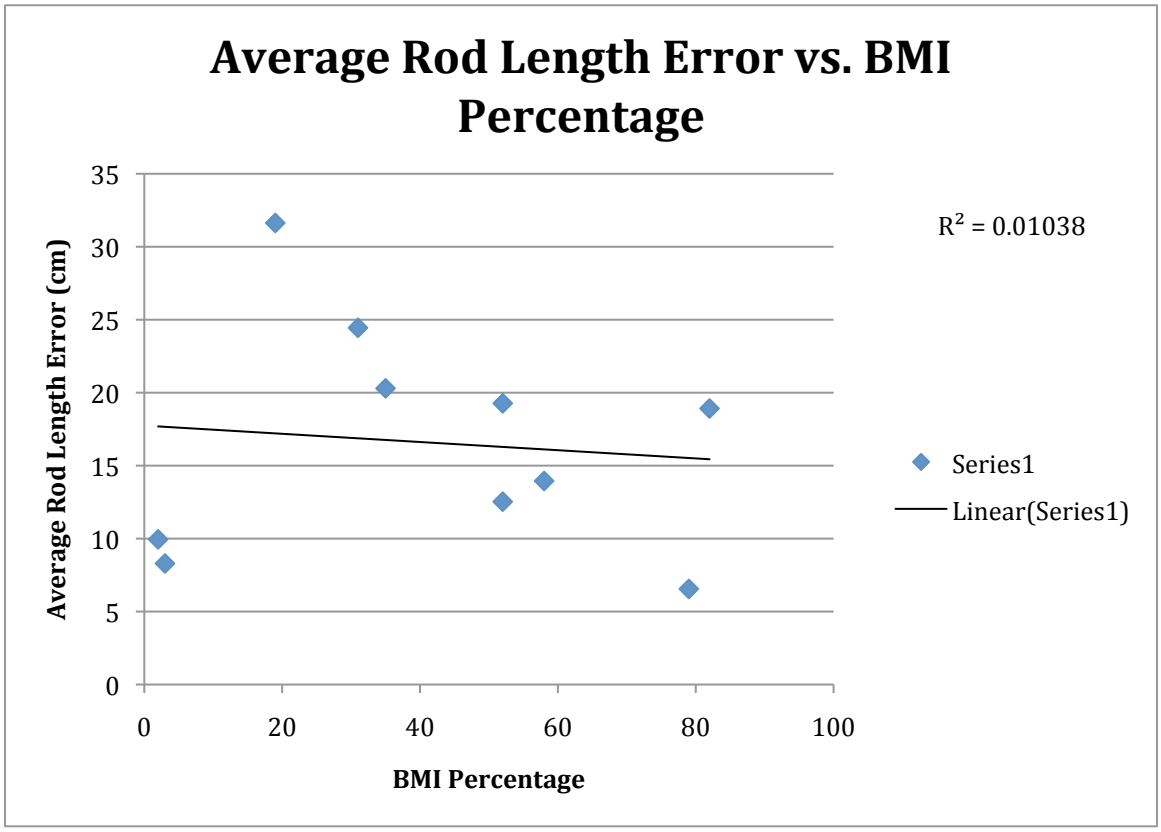

Figure 1 (Average Rod Length Error vs. BMI Percentage)

Results from the 5-question survey relayed specific information about the subjects' growth and other proprioceptive measures. Question 1 asked about the subject's shoes and if they have been growing out of their shoes quickly. Results from this question were generally consistent across all 10 subjects. All of the subjects reported changes in shoe size maximally within 1 year. Four out of the 10 subjects reported growing out of their shoes in under a year and 1 subject reported having grown 2 shoe sizes in the past year.

The second question asked about the girls' clothes and if they were too small. Survey answers showed that only 2 out of the 10 girls have not needed to obtain new clothes recently. Of note, 1 of the 2 girls (who had previously been diagnosed as obese) had lost 9 pounds within the past year and was still steadily losing weight. She reported that she has able to fit into old clothes because of the decrease in weight.

Question 3 and 4 asked the subject how many times they had tripped over objects and bumped into objects (respectively) in the past 5 days. Four out of 10 girls reported not tripping, 1 subject tripped once, 2 have tripped twice, and 3 girls reported tripping 3 or more times (one subject reported tripping frequently). Six out of the 10 girls reported bumping into objects (2 girls reported bumping into objects once, 1 girl reported bumping herself twice, and 2 girls reported frequent bumps into objects). Four girls reported not bumping into any objects in the last 5 days. One of the 2 girls who reported bumping into objects frequently stated that she habitually discovers bruises on her body without knowledge of where she obtained them.

Table 1: 5 Question Survey Results

Question	Subject 1	2	3	4	5	6	7	8	9	10
1: Shoes	Has had to buy shoes once this year and once last year.	Has had to buy shoes once already this year.	Has had to buy new shoes at the beginning of every year.	Shoes from last year are too small.	Needs new shoes soon. Last pair of shoes bought one year ago.	Needs new shoes soon. Last pair of shoes bought at the beginning of the school year.	Bought new shoes at the beginning of school year and now are more snug.	Grew two shoe sizes in the past year.	Some shoes from last year are small.	Bought new shoe at the beginnin of July and now are more snug.
2: Clothes	Needs to buy clothes about two times per year	Has not needed to buy new clothes recently.	Pants are too short and tight.	Clothes are too small.	Growing into old clothes.**	Bought new clothes a couple weeks ago.	Two year old clothes now too small.	Steadily growing out of them.	Many clothes are too small.	Shirts are small.
3: Tripped in last 5 days	Tripped twice	Has not tripped.	Tripped once	Tripped three times (once going upstairs).	Tripped twice.	Has not tripped.	Has not tripped.	Has not tripped.	Has tripped a few times (tree roots)	Trips frequentl
4: Bumped in last 5 days	Has not bumped into anything	Has not bumped into anything	Has bumped body twice (stubbed toes and bumped shin).	Has many bruises and does not know where they came from.	Has bumped twice (into a table and stubbed her toes).	Has bumped herself while doing handstands.	Has not bumped into anything	Has bumped into the door frame.	Has not bumped into anything	Bumps frequentl
5: Picking up objects	No answer.	No answer.	Thinks objects are generally heavier than they actually are.	Thinks objects are generally lighter than they actually are.	Thinks objects are generally heavier than they actually are.	Thinks objects are generally lighter than they actually are.	Thinks objects are generally lighter than they actually are.	Varies	Thinks objects are generally heavier than they actually are.	Varies.

**Subject 5 (previously overweight) lost 9lbs in the past year and is still steadily losing weight.

The final question on the survey investigated the perceived object weights. 3 subjects reported thinking objects are generally heavier than they actually are, 3 reported thinking objects are generally lighter than they actually are, 2 answered that perceived weight varies between objects and 2 subjects chose not to answer the question.

In support of our hypothesis, the testing resulted in a general trend representing adolescent difficulty in correctly estimating the various lengths of the rods tested. Figure 2 represents each of the 10 subjects average error (Absolute Value of the Estimated Average - Exact Length) for each rod number. Compared to the findings from Solomon, Turvey and Burton (1989) where adults were able to accurately estimate the length of each rod, the adolescent girls had reduced aptitude to estimate the rod lengths, especially longer rod lengths. Figure 2 demonstrates that the adolescent girls' ability to estimate the rods decreased as the length of the rods increased.

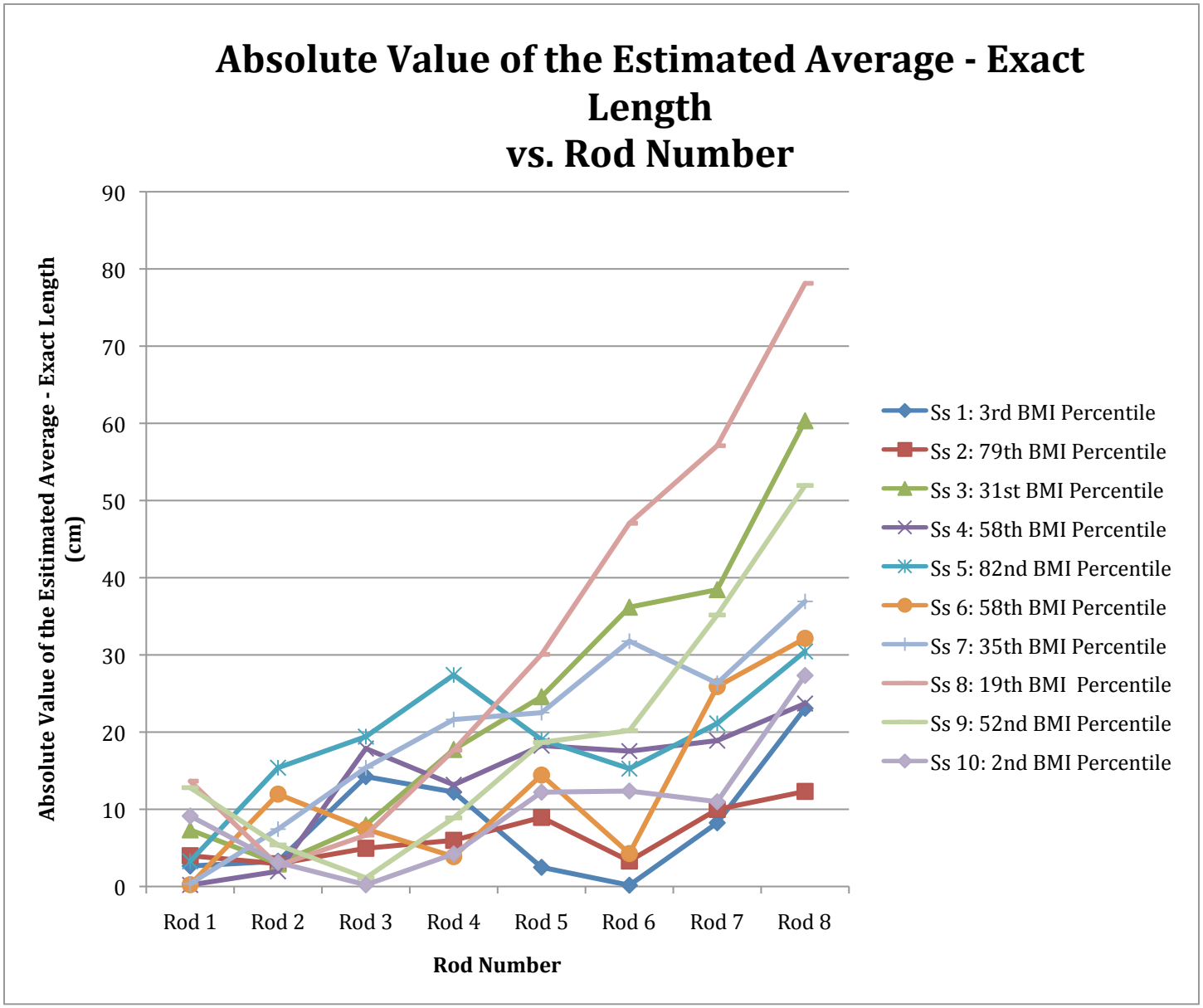

Figure 2 (Absolute Value of the Estimated Average of Each Rod – Exact Length of Each Rod vs. Rod Number)

Discussion

Growing adolescents often have a tendency to be awkward or clumsy most likely due to underdeveloped perceptual system. Based upon the results of this study, adolescent girls between 9.5 and 10.5 years old are not fully perceptually developed based on haptic proprioception testing. The girls displayed a significant relationship; as the length of the rod increased, the girls' ability to estimate the correct length of the rod decreased.

Due to the nature of the study and the willing subject population there was difficulty in recruiting subjects on BMI extremes (45^{th} percentile and below, 85^{th} percentile and above). Perhaps more time could have granted the possibility to search for more subjects within the constraint, but for the purpose of this study, healthy individuals (percentiles 46-84) were also included. BMI proved to be insignificantly related to the average error of the rod length estimates. The statistical insignificance found between average error and BMI percentile may be due to the fact that the rate of growth of each subject (growth in height and adiposity) is unknown.

It is possible that the amount of time between the last growth spurt (salutatory growth episodes) and the current growth status will affect how the adolescent adapts to her body (Lampl and Johnson, 1993). Every individual is different and the rate of development varies (Tanner et al. 1965). Even though the study targeted a small population, there is still great opportunity for deviation. A way to limit the discrepancy between individuals would be to conduct a longitudinal investigation in growth rate allowing the researcher to identify the largest rate of physical growth and when to appropriately conduct this study (i.e. during the growth spurt).

Using the information from the 5-question survey, growth rate can be inferred, previous growth spurts can be noted and current proprioceptive ability in other areas of the body besides haptics can be measured. Shoe size changes are notable markers for predicting the timing of pubertal growth (Busscher et al., 2011). The results of the survey question about shoes provide longitudinal evidentiary support as to the rate of growth of each subject. Because all of the subjects noted change in shoe size (some greater than others) it is safe to assume growth was occurring as well. For those girls that reported substantial foot growth (needing to buy shoes more than once per year) their rate of growth is concluded to be even larger than the other subjects and therefore less likely to be able to accurately estimate the length of the rods, especially the longest rods. For instance subject 8 reported that she has grown at least 2 shoe sizes within the past year and it was shown in Figure 4 that she had the highest average error of each rod estimate than any of the other subjects.

Reports from the clothing survey question determined that 2 of the subjects (subject 2 and subject 5) have not needed to buy new clothes recently. Interestingly, the average error of their estimates were the most consistent across all of the subjects tested establishing that current growth plays a large role in the ability to predict rod length. Therefore as adolescent girls are skeletally growing, the perceptual system is struggling to maintain growth as well. Subject 5 had an interesting background story pertaining to BMI and growth. Although she has continued to grow in height, in the past year she has lost 9 pounds and is still steadily decreasing in weight. She was previously diagnosed as being overweight (close to obesity). Her doctor and family worked with her to create a healthier lifestyle (healthy diet and increased physical activity). She reported now

growing into old clothes that once fit her when she was overweight, but now fit because she is growing in height and losing adipose tissue throughout the body.

Questions 3 and 4 referred to current clumsiness/lack in proprioception. There were little significant correlations between the average error of the estimations and tripping over or bumping into objects. This is possibly due to the nature of surveys because they are based on subject recall. If the subject is used to bumping into or tripping over objects it may be off their radar to remember such occurrences.

No general correlation can be made from question 5 (picking up objects) possibly because the subjects may not think about weight of objects prior to lifting them. Also, this question could be difficult for the subject to understand exactly what the researcher was asking. The reason for this question was to try to understand the subjects' perceptual capability because the rod weight had an effect on how the subject perceived it's weight (Turvey, 1996). In future studies a clearer question and/or a more definite test must be done in order to properly understand the subjects' perceptual competence.

Many limitations existed in the study. First of all, the number of subjects does not allow the study to make meaningful conclusions based on the general population. All of the subjects were Caucasian girls from the State College, Pennsylvania area. It is possible that different social and cultural backgrounds may influence different growth patterns and therefore offers different results (Buckler and Wild, 1985). Moreover, for the survey usage, reliance on the recollection of 9.5 to 10.5 year old girls was needed. Perhaps if the girls were asked to visit the lab twice, once to obtain a log to write down number of tripping over and bumping into object instances as well as object weight perception and then a second time for the actual haptic testing, the researcher may be able

to attain more useful background information. Also, BMI is not a highly accurate measure of body composition. Bod Pod, hyrostatic weighing or DEXA scan usage are more appropriate to understand changes in body composition over time. Most obviously, the largest limitation of the study of the study was the lack of time. Ideally this study should be longitudinal. This way, researchers have the ability to track changes in the subject overtime and accurately determine their rate of growth and occurrence of peak height velocity. Application of these changes will help to understand why adolescent clumsiness occurs and how best to avoid consequences of the clumsiness (injury).

Hinged on extensive research, this was the first study to examine the relationship of haptic proprioception development using the techniques from Solomon, Turvey and Burton (1989). The conclusions made are stepping-stones to understand female adolescent perceptual growth and must be further researched in order to grasp a complete comprehension of adolescent clumsiness. Future studies will help to unfold the mysteries of adolescent growth and may point towards injury solutions and prevention.

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Appendix:

Appendix A: Informed Consent Form

Informed Consent Form for Biomedical Research
The Pennsylvania State University – Parents

Title of Project: Adolescent Clumsiness and the Lag of the Haptic Perceptual System

Principal Investigator: Dr. Karl Newell
21 Recreational Hall, University Park, PA 16802
(814) 571-1812; kmn1@psu.edu

Co-Investigator: Rachael Koppel, Undergraduate Student
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(607)339-8837; rvk5084@psu.edu

1. **Purpose of the Study:** The purpose of this research study is to examine the effects peak growth height on the adolescent's nervous system specifically of the hand.

2. **Procedures to be followed:** Your child will be asked to answer a 5-question survey that will ask questions about her changes in height that she has noticed as well as frequency of certain forms of clumsiness i.e. tripping or bumping into objects. After the survey several body measurements will be taken (height, weight, and hip circumference) and then your child will sit down to test her perception of length using rods of varying densities.

3. **Discomforts and Risks:** There are no risks in participating in this research beyond those experienced in everyday life.

4. **Benefits:** Your child may learn more about herself by participating in this study and might have a better understanding of how important movement is to her.

   This research might provide a better understanding of how adolescent growth affects their motor control and capability. This information could help plan programs and make adolescent services better.

5. **Duration:** It will take about 1 hour.

6. **Statement of Confidentiality:** Your child's participation in this research is confidential. The data will be stored and secured at 21 Recreational Hall in a locked/password-protected file. The Pennsylvania State University's Office for Research Protections, the Institutional Review Board and the Office for Human Research Protections in the

Department of Health and Human Services may review records related to this research study. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

7. **Right to Ask Questions:** Please contact Rachael Koppel at (607) 339-8837 with questions, complaints or concerns about this research. You and your child can also call this number (814) 863-4037 if you feel this study has harmed you. If you or your child have any questions, concerns, or problems about your child's rights as a research participant or would like to offer input, please contact The Pennsylvania State University's Office for Research Protections (ORP) at (814) 865-1775. The ORP cannot answer questions about research procedures. Questions about research procedures can be answered by the research team.

8. **Payment for participation:** Your child will receive $15 for her participation in the study.

9. **Voluntary Participation:** You and your child's decision to be in this research is voluntary. Your child can stop at any time. Your child does not have to answer any questions she does not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits your child would receive otherwise.

10. **Injury Clause:** In the unlikely event your child becomes injured as a result of her participation in this study, medical care is available but neither financial compensation nor free medical treatment is provided. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

If you agree to allow your child to take part in this research study and the information outlined above, please provide her name and date of birth below along with signing your name and indicating the date below.

You will be given a copy of this signed and dated consent form for your records.

_____ _____

Printed Name of Child Date of Birth

_____ _____

Parent's Signature Parent's Printed Name

_____

Date

_____ _____

Signature of Person Obtaining Consent Printed Name of Person Obtaining Consent

_____

Date

Appendix B: Informed Child Assent Script

Informed Child Assent Script for Biomedical Research
The Pennsylvania State University

Title of Project: Adolescent Clumsiness and the Lag of the Haptic Perceptual System

Principal Investigator:
Dr. Karl Newell
21 Recreational Hall
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Co-Investigator:
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Welcome! My name is Rachael and today if you want to help out with my research we will be looking to see how your growing body knows how big you are and how big things are around you.

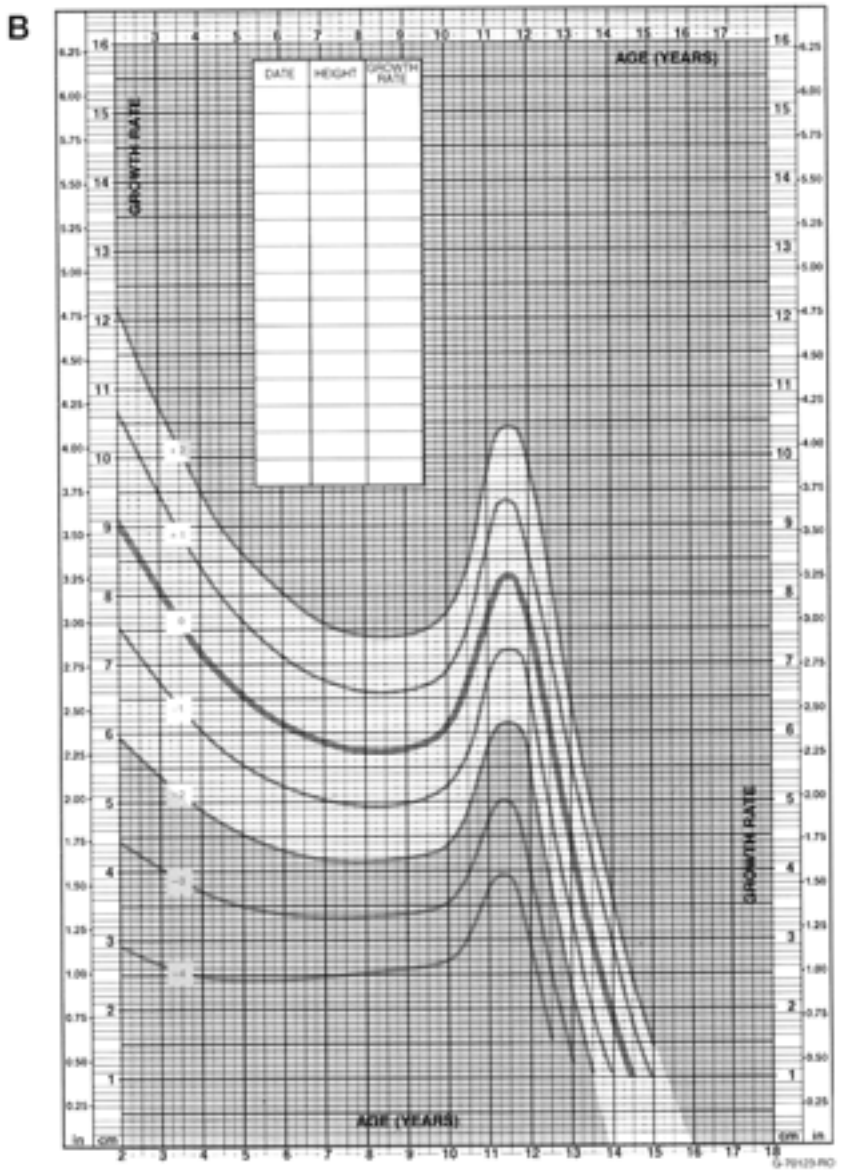
Do you ever trip or fall or run into things? I think that this might happen because right now you are growing so quickly that your mind just can't catch up yet! So we are going to check it out together and see!

Today there are a couple things I am going to ask you to do, but if you don't want to do one of the things or any of them that's ok, you just let me know.

The first thing I am going to ask you to do is answer a couple questions about how quickly you have been growing recently and how many times you trip or bump into things. Next is am going to measure how tall you are, how much you weigh and the length all the way around your hips. After that you will sit in a chair next to a big white screen. One of your hands will be on the other side of the screen and I will place a rod in your hand and then ask you to take your best guess at how big it is without seeing it. It's ok if you are wrong. It's not a test. I'm just going to see how close your guess is to the real rod length.

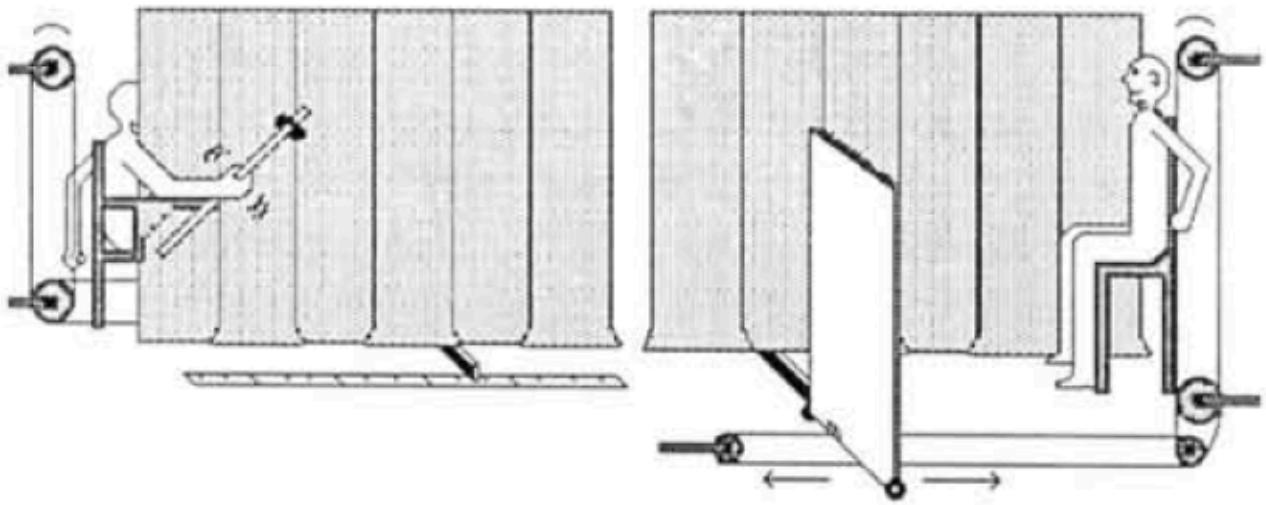
After that, then you're done! Are you ready to get started?

Appendix C: Height Growth Velocity Curve



Graph: Tanner et al. (1985)

Appendix D: Apparatus



ACADEMIC VITA

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Education

B.S., Kinesiology, 2013, Pennsylvania State University, State College, PA
Honors in Kinesiology

Honors and Awards

- 1st place winner of The Penn State University Special Collections Library local version of the Society of American Archivists "I Found it in the Archives." Research assistant for Mark Dyreson, Professor of Kinesiology, Pennsylvania State University (January 2012)
- Dean's List Fall (2009-Present)
- Frances A. and Ruth C. Wodock Scholarship (2010-2011, 2011-2012)
- Schreyer Honor's College Academic Scholarship (2009-Present)
- Schreyer Honor Scholar (2009-Present)

Association Memberships/Activities

- Penn State Crew President (2012-Present), Secretary (2011-2012), Member (2010-Present)
- Penn State Crew IFC/Panhellenic Dance Marathon (THON) (2010-2013)
- Penn State Kinesiology Club Member (2009-Present)
- Penn State Gymnastics Club Member (2009-2010)

Professional Experience

Physical Therapy/Exercise Facility Internships/Volunteer:

- Intern at FITOLOGY, State College, PA (Spring 2013)
- Phoenix Rehabilitation and Health Services, State College, PA (Summer 2012)
- McCune and Murphy Physical Therapy, Trumansburg, NY (Summer 2011)
- Lemont Physical Therapy, State College, PA (Spring 2011)
- Seneca Physical Therapy of the Fingerlakes, Watkins Glen, NY (Summer 2010)

Teaching Assistant

- Undergraduate Teaching Assistant for Kinesiology 202 (Functional Human Anatomy) (Fall 2013)

Gymnastics Coach

- Head Over Heels Gymnastics, Ithaca, NY (2004-2012)

Research Experience (besides Senior Honors Thesis)

- Mark Dyreson, Professor of Kinesiology, History of Sport and Culture at the Pennsylvania State University (Fall 2010)

Professional Presentations

- Sports Medicine Conference presented by Island Health and Fitness with Cayuga Medical Center August 6, 2011, Ithaca, NY