2010

Impacts of Non-Custom Mouthguards on Muscular Strength and Vertical Jump Height in Collegiate Athletes

Magda Reda Abdelfattah

BARRY UNIVERSITY

SCHOOL OF HUMAN PERFORMANCE AND LEISURE SCIENCES

IMPACTS OF NON-CUSTOM MOUTHGUARDS ON MUSCULAR STRENGTH AND VERTICAL JUMP HEIGHT IN COLLEGIATE ATHLETES

BY

MAGDA REDA ABDELFATTAH

A Thesis submitted to the
Department of Sport and Exercise Sciences
in partial fulfillment of the
requirements for the Degree of
Master of Science in
Movement Science
with a specialization in
Injury and Sport Biomechanics

Miami Shores, Florida
2010

ACKNOWLEDGEMENTS

The process of writing this thesis was a long and tedious one; therefore, it is imperative that I recognize those who have helped me along this journey.

First of all, I would like to thank my advisor and committee chair, Dr. Claire Egret. Her academic brilliance was undoubtedly helpful to me throughout my education at Barry University, particularly in the completion of this project. Her mentorship provided the encouragement, insight, and guidance that were needed for me to always ensure my best efforts.

I have sincere gratitude for Dr. Kathryn Ludwig, who was a great contributor to my knowledge of the biomechanics field. Her expert teaching most definitely facilitated an easier path on my way to earning this degree, and I am grateful to her for this reason.

Dr. Sue Shapiro, who also served on my thesis committee, provided me with the intellect to take my thesis to higher level. To have her on my committee was an absolute pleasure and am indebted to her for the valuable advice with which she provided me.

I would also like to thank Dr. Carl Cramer, Dr. Monique Butcher-Mokha, and the staff of the Athletic Training lab at Barry University. Their assistance was crucial to the completion of this endeavor, and I am deeply appreciative of their help.

Lastly, I would like to thank and dedicate this thesis project my family. To my father, Dr. Reda A. Abdel-Fattah, and to my mother, Dr. Mervat M. Alattar, who have given me the best role models one could possibly have, and who inspire me every day to do great things. I could not have completed this project without my siblings, Kareem, Sarah, Sharif, and Deana; their unconditional love and support will always provide me with the strength and persistence I will forever need to pursue my life goals and aspirations.

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ABSTRACT

The purpose of this study was to examine the impacts of non-custom mouthguards on muscular strength performance of the knee and shoulder joint, as well as jump height in collegiate athletes who do not manifest Temporomandibular Joint Disorder (TMD). Twenty-four college students volunteered to participate, all of who were current members of varsity-level teams. The subjects were divided into four groups; two of these groups used an upper mouthguard, and the other two groups used a double mouthguard; there were also differences in the order in which the mouthguard was used. The data for muscular strength was taken as the participant was seated in a stabilized chair of a Biodex System 3 dynamometer, while the jump height was assessed using a Vertec jump height apparatus. Repetitions of knee flexion/extension and shoulder external rotation/internal rotation at 60 degrees per second and 180 degrees per second were taken, as well as jump height differentials. Measurements were recorded for the single peak torque and total work, as well as jump height for each of the sets and jumps for all groups; the average of the first three sets and the average of the last three sets were used for data analysis.

Seventeen 4 x 2 mixed-model ANOVAs were calculated to examine the effects of group and test (with mouthguard/without mouthguard) on each measured variable. Significant effects were only found for peak torque away at 60 degrees per second and for total work away at 180 degrees per second; all other data was deemed not significant. Results may have been affected by inappropriate fit of mouthguard treatment or the inability to exclude asymptomatic TMD participants properly. Future research should investigate the effects of mandibular adjustment on the different joints of the body, as

well as utilize varying sizes of mouthguards while still maintaining the non-custom aspect of the appliances.

CHAPTER I: INTRODUCTION

It is recognized that the use of mouthguards for protection in sports is an important issue; several athletic organizations have adopted mandatory regulations for the utilization of these oral appliances during play (Knapik et al., 2007; Von Arx, Flury, Tschan, Buergin, & Geiser, 2008). Although many athletes understand the idea that mouthguards should be worn for injury prevention of the mouth and surrounding tissues, relatively few individuals regularly wear a mouthguard during training and competition in the cases in which they are not mandated to wear one, citing reasons such as difficulty with conversation, sense of discomfort, feelings of vomiting, breathing difficulties, and an increased secretion of saliva (Tanimoto et al., 2007). Other reasons for the lack of mouthguard use for contact sport athletes included a worry that mouthguards may interfere with athletic performance (Lieger & Von Arx, 2006).

Overall, it may depend on the type of sport in which an athlete participates that determines whether or not he or she is aware of the importance of the use of a mouthguard. For example, track and field athletes are aware of the term “mouthguard”, yet very few understand and are aware of the necessity of a mouthguard during competition (Mori et al., 2007). This is in comparison to contact sport athletes, such as soccer, basketball, handball, and ice hockey players, among whom most are aware of the importance of the use of mouthguards, whether or not they personally utilize them or not (Lieger & Von Arx, 2006). To emphasize this attitude in athletes, a study evaluating the use of mouthguards divided participants into two groups, one group that was mandated to wear a particular mouthguard and one group that was not mandated to use the mouthguard. As a result, all of the participants in the mandated group wore the mouthguard, whereas 91% of the athletes in the non-mandated group did not wear their mouthguards (Komiyama et al., 2008).

In spite of the strong opinions of some athletes that discourage their own use of mouthguards for the given reasons, there are other contributing factors as to why mouthguard use is so rare. For one, the emphasis on the importance of a protective mouthguard in sports is lacking, particularly by coaches, athletic trainers, and fellow athletes. In addition, the potential funding for protective appliances is minute, as well as the support needed from administration and officials to make mouthguard use obligatory (Lieger & Von Arx, 2006).

Different sports result in different mechanisms of sporting accidents, and the presence or deficiency of mouthguard use can ultimately affect the severity of the potential injuries that result; yet even in high contact sports such as hockey and soccer, the majority of athletes do not wear mouthguards. Trauma to the face can potentially cause a multitude of different possible injuries: tooth loss, soft tissue injury, fracture to the jaw, fracture to facial bones, or even cerebral damage. In addition, the athlete can potentially endure psychological impacts as well as a significant economic investment in order to deal with the repercussions of this type of injury (Lieger & Von Arx, 2006). If an athletic advantage was attributed to mouthguard use, there would be a possibility of an increase of protective appliance use amongst athletes who are prone to facial injuries in their respective contact sport.

Mouthguards are essentially soft, oral appliances. Therefore, in addition to protecting the teeth to prevent tooth loss during a high-contact activity, it can also be used to reposition the mandible and change the occlusion of the teeth. A complex relationship exists between the joint of the jaw – the Temporomandibular Joint (TMJ) – and the muscles of the head and neck, as well as the entire body. By providing an appliance that repositions the mandible, it is possible to reduce stress and tension in the muscles, improve abnormalities in body posture, and increase physiological and exercise performance (McArdle et al., 1984). Alignment of the TMJ further stabilizes the mandible, and this stabilization leads to corrected head posture and alignment of the cervical vertebrae (McArdle et al., 1984). This point is further supported by the concept of the human body being a "kinetic chain"; the kinetic chain is a biomechanical model which depicts the body as a linked system of interdependent segments, often working together in order to complete a desired action (Putnam, 1993). The contribution of the entire body during sport activities is illustrated with this model, as opposed to a focus on the individual segments (McMullen & Uhl, 2000).

A variety of different types of mouthguards are available to athletes, but only certain types can be purchased in sporting good stores, where they are easily accessible to the athlete. Non-custom mouthguards include "stock" (non-custom) mouthguards – which have no fitted bite, and "boil-and-bite" mouthguards. These mouthguards are more affordable than the custom mouthguards made by dentists. Although the varying price difference, each and every mouthguard type has the potential ability to play a role of both a stabilizer (by repositioning the mandible and holding it in place) and a shock absorber, by reducing the stress sent to the head and brain (Knapik et al., 2007).

Sports at the collegiate level require muscular strength for both short bursts of activity and the ability to maintain endurance throughout a game. Most athletic programs at this level will provide mouthguards to their athletes only with the intention to protect the teeth, perhaps after a traumatic injury; in addition, high-contact sports, such as football and hockey, are the activities in which these mouthguards are typically given to the athletes (whereas other sports that are often found in collegiate programs do not usually provide or necessarily endorse the use of mouthguards to their athletes). Considering the potential benefits of using a mouthguard, it would be of interest to explore the effects of different types of non-custom mouthguards on isokinetic muscular strength, as well as a functional application reflecting athletic activity, such as vertical jump height.

Statement of the Problem

The overall use of mouthguards in collegiate-level sports is lacking. Considering the potential benefits of using a mouthguard, it would be of interest to investigate the impacts of different types of non-custom mouthguards on isokinetic muscular strength and jump height in such athletes. Although there is current literature that addresses the effects of mouthguard use on muscular strength as well some functional applications of mouthguard use, these studies have had conflicting results. This may have been due to the fact that they have failed to address certain aspects that should be considered. For example, those subjects who exhibit Temporomandibular Joint Disorder have not been excluded in these studies; perhaps this has contributed to the inconsistencies in results (Burkett & Bernstein, 1982; Stenger, Rickets, Lawton, & Wright, 1982; Yates et al., 1984). In addition, there has been an absence of literature on this topic that allows the data to be generalized to all athletes, as opposed to athletes who participate in one particular sport. Therefore, by considering the limitations that may have previously affected the results of similar studies, this study intended to determine the impacts of mouthguard use on isokinetic muscular strength as by means of peak torque and total work in collegiate level athletes. Additionally, a functional application was also assessed with an examination of vertical jump height.

Purpose of the Study

The use of oral appliances to reposition the TMJ has become increasingly popular in the Sports Dentistry field (McArdle et al., 1984). Past studies have had contradictory results in examining the effect of mouthguards on muscular strength and functional capabilities. However, these studies did not account for subjects who exhibited symptoms of Temporomandibular Joint Disorder (TMD). In order to truly evaluate the effectiveness of various mouthguards on an athlete's muscular strength, it was essential for this study to exclude those athletes that display symptoms of TMD. This provided more control over the study, given that TMD athletes are more than likely have improvements with any type of oral appliance (Tecco, Epifania, & Festa, 2008); non-TMD athletes were predicted to reveal more controlled results. Therefore, the purpose of this study was to determine the effects of non-custom mouthguards on repeated muscular strength tests and vertical jump height in collegiate-level athletes who do not exhibit symptoms of Temporomandibular Joint Disorders. Although many studies have reviewed the use of Mandibular Orthopedic Repositioning Appliances (MORA) on strength, no literature reviews the effect of non-custom mouthguards on strength; this is important because of the factor of cost; MORAs typically range from $300 - $1300 (Yates, Koen, Semenick, & Kuftinec, 1984), while over-the-counter mouthguards typically cost anywhere from $1 -

$50. By knowing the outcome of this study, athletes will be able to decide whether or not the employment of a mouthguard can increase their isokinetic muscular strength and furthermore have a practical use by increasing their jump height.

Significance of the Study

Despite the widespread use of mouthguards in sports like hockey and football, there is a severe lack of athletes who use mouthguards in other activities. The results of this study may be influential in that displaying an increase in strength of the participants with mouthguard use (and furthermore functional improvements such as jump height), athletes may be more receptive to the use of mouthguards as a means of increasing their athletic performance.

Limitations

The limitations of this study were as follows: all participants were mandated to be collegiate level athletes at the time of the study; as a result of this self-selection, this study did not use a random design. The participants' diets were not controlled and, therefore, might have influenced the outcome of the study. In addition, there was no psychological pressure as there would be in a real-world exhibition of muscle strength.

Delimitations

The delimitations placed on this study were the following: this research was conducted in the Athletic Training and Biomechanics laboratories in the School of Human Performance and Leisure Sciences at Barry University, in Miami Shores, Florida.

All participants were mandated to be collegiate-level athletes, who trained at least ten hours per week at the time of the study. In addition, participants were asked to continue their normal training and diet routines at the time of the study. The subjects who volunteered for data collection were only allowed to continue their participation in the study if they did not exhibit any symptoms of Temporomandibular Joint Disorder. Information on subjects pertaining to these topics will be acquired through a Subject Profile Questionnaire (Appendix B).

Assumptions

At the time of the study, it was assumed that the participants are representative of the entire population of male and female (Division II) collegiate-level athletes. All participants understood the directions that are given in the study, and provided their maximal effort. The research analysis and interpretation is seen accurate and non-biased, and the equipment used is valid and reliable.

Variables

Dependent Variables

The dependent variables were as follows:

- The muscular strength of the knee extensors, measured as peak torque and total work.
- The muscular strength of the knee flexors, measured as peak torque and total work.

- The muscular strength of the shoulder external rotators, measured as peak torque and total work.
- The muscular strength of the shoulder internal rotators, measured as peak torque and total work.
- The vertical jump height, measured in meters.

Muscular strength variables were determined by the Biodex System 3 Dynamometer, while vertical jump height is determined by the Vertec vertical jump height-testing device.

Independent Variables

The independent variables in this study were the bite condition as well as the speed of concentric contractions of the muscles; bite condition included the following possibilities:

- Upper, Stock mouthguard (which covers the upper teeth when worn)
- Double, Stock mouthguard (which covers the upper and lower teeth when worn)

Speed of concentric contractions of the muscles includes:

- Isokinetic knee flexion and extension at 60 degrees per second
- Isokinetic knee flexion and extension at 180 degrees per second
- Isokinetic shoulder internal rotation and external rotation at 60 degrees per second

- Isokinetic shoulder internal rotation and external rotation at 180 degrees per second

Research Hypotheses

To ensure validity and reduction of error, the following research hypotheses were statistically evaluated in order to determine the possible differences between the independent variables:

- It is expected that the upper, stock mouthguard will significantly improve isokinetic muscle strength of the knee extensor and flexor muscles in collegiate level athletes in terms of peak torque and total work.
- It is expected that the upper, stock mouthguard will significantly improve isokinetic muscle strength of the shoulder external and internal rotator muscles in collegiate level athletes in terms of peak torque and total work.
- It is expected that the double, stock mouthguard will significantly improve isokinetic muscle strength of the knee extensor and flexor muscles in collegiate level athletes in terms of peak torque and total work.
- It is expected that the double, stock mouthguard will significantly improve isokinetic muscle strength of the shoulder external and internal rotator muscles in collegiate level athletes in terms of peak torque and total work.
- It is expected that the upper, stock mouthguard will significantly improve vertical jump height in collegiate level athletes.
- It is expected that the double, stock mouthguard will significantly improve vertical jump height in collegiate level athletes.

Operational Definitions

- “Boil-and-bite” mouthguards – Presently, this is the most commonly used mouthguard on the market. Made from thermoplastic material, they are immersed in boiling water and formed in the mouth by using finger, tongue, and biting pressure (Padilla, 2006).
- Kinetic Chain - A biomechanical model that depicts the body as a linked system of interdependent segments, often working together in order to complete a desired action (Putnam, 1993).
- Knee Extensor Muscles – The muscles that assist in extension of the knee (the quadriceps muscle group consisting of the rectus femoris, vastus lateralis, vastus intermedius, vastus medialis muscles).
- Knee Flexor Muscles – The muscles that assist in the flexion of the knee (namely, the hamstrings muscle group consisting of the semi-tendinosis, semi-membranosis, and biceps femoris muscles, as well as the sartorius, gracilis, popliteus, and gastrocnemius muscles).
- Malocclusion – A deviation in intramaxillary and/or intermaxillary relations of teeth that presents a hazard to the individual’s well being (Zwemer, 1982).
- Isokinetic Muscular Strength – The subject’s strength as a result of his or her performance while using the Biodex System 3 Dynamometer.
- Collegiate athlete – Athletes that belong to the intercollegiate athletic program at the varsity, Division II level.
- Double, Stock Mouthguard – A stock mouthguard that covers both the lower and the upper set of teeth when worn; it does not have a custom fit to the teeth.

- Over-the-counter mouthguard – A mouthguard that can be purchased at a sporting goods store or sporting goods section of a retail store.
- Shoulder external rotator muscles – The muscles that assist in the external rotation of the shoulder (the deltoid, infraspinatus, and teres minor muscles).
- Shoulder internal rotator muscles – The muscles that assist in the internal rotation of the shoulder (the deltoid, subscapularis, teres major, latissumus dorsi, and pectoralis major muscles).
- Squat jump – In this study, the functional application measured to determine vertical jump height; the athlete squats by bending both knees (while standing under the Vertec). Then, the athlete jumps off both feet simultaneously, as high as he or she can, hitting the highest vine on the Vertec apparatus.
- Stock mouthguard - The stock mouthguard, available at most sporting good stores, come in limited sizes (usually small, medium, and large). The prices range approximately from $3 to $25. These protectors are ready to be used without any further preparation, and therefore do not have a custom fit to the teeth. They lack any retention, and therefore must be held in place by constantly biting down (Padilla, 2006).
- Symptoms of Temporomandibular Joint Disorder – Symptoms of TMD could be one or a combination of any of the following: clicking of the jaw; pain when moving the jaw; irregular movement of the jaw; difficulty chewing or speaking; pain in the head (headache); pain in the ear; pain in the sinus; pain in the throat; dizziness; hearing problems (Abdel-Fattah, 1992).

- Temporomandibular Joint Disorder (TMD) – A malfunction and/or pain arising from the jaw joint that articulates the lower jaw to the skull (Abdel-Fattah, 1992).
- Upper, Stock Mouthguard – A stock mouthguard that covers only the upper set of teeth when worn; it does not have a custom fit to the teeth.
- Vertical Jump Height – As measured by the Vertec Vertical Jump Height testing device, it is the maximum height (measured in centimeters) attainable achieved by jumping off two feet simultaneously (squat jump).

CHAPTER II: LITERATURE REVIEW

In order to appropriately examine the effects of non-custom mouthguards on repeated muscular strength tests and vertical jump height in collegiate-level athletes, a thorough examination of the topics included in such research, in addition to past studies which examine similar motifs must be completed. A wide-variety of experiments have been completed concerning oral appliances and athletic performance, as these are applicable to creating a foundation for the reasoning of this study.

Biomechanical Aspects of the Jaw

First, one must understand the biomechanics of the joint and surrounding structures that control the movement of the mandible. Anatomically, the Temporomandibular articulation consists of a hard skeleton including the mandibular and maxillary bones as well as teeth, embedded in a soft functional matrix (fascia, muscles, ligaments, blood and lymph vessels, and nerves) which provides stability during closed-mouth functions and balance during open-mouth activities (Abdel-Fattah, 2008).

Although this joint function is used a countless number of times throughout a single day by the human body, very little literature to common knowledge is available reflecting the biomechanical aspects of the jaw. It was once thought that the jaw was not a "weight-bearing" joint and that no compressive loading of the jaw occurs (Robinson, 1946). However, more recent research has resulted in a change in this accepted notion. The jaw is a diarthrodial joint; therefore, the musculature pulls across the joint (DuBrul & Menekratis, 1981) creating a load. The mandible functions much like a Class III lever system and when the muscles contract, the forces produced create loads on both the teeth and within the joint (Barbenel, 1969). Shearing forces are the main feature of force types on the TMJ, while other forces that occur are often compression or torsion forces; in addition, there is sufficient evidence to indicate that the mandibular condyles take on differing loads depending on the occlusal contact position and the amount of tension created by the muscles. The health of the joint determines the frequency, duration, magnitude, direction, and location of the loads (Mohl, Zarb, Carlsonn, & Rugh, 1988).

Many factors can influence this articulation of the joint, contributing to instability. Depending on the degree and duration of a trauma, thinning, displacement, damage, or deformity of the articulating disc caused by overloading leads to degenerative changes and skeletal-dental imbalance, as well as strain of the surrounding muscles, especially those of the craniofacial area (Abdel-Fattah, 2008). Disc displacement further causes overstretched tissues, leading to instability of the area. In addition, a degeneration of the mandibular condyle can disturb the Temporomandibular articulation by causing a mechanical imbalance; the degenerated mandibular condyle is either flattened on the anterior or superior surfaces, or has a pointed superior surface. These formations can cause displacement, reduction, or even rupture of the disc (Abdel-Fattah, 2008).

Occlusal Effects of Mandibular Function

Typically, occlusion refers to the articulation of the upper and lower teeth; however, the conceptual view of occlusion must also include all of the functional, parafunctional, and dysfunctional relationships that exist within the masticatory system as a result of the contacts of the upper and lower teeth (Ash & Ramfjord, 1982). The *functional* movements of the mandible are those found in speech, mastication, and swallowing; the *parafunctional* movements are the tooth to tooth contacts (clenching and grinding), tooth to soft tissue contacts (lip biting and thumb sucking), soft tissue to soft tissue contacts (abnormal swallowing), and foreign object to tooth contacts (pencil biting); the *dysfunctional* movements of the mandible are abnormal or impaired movements caused by a hyperactivity in the craniofacial musculature or a derangement of the articular disc (Howat, Capp, & Barrett, 1991).

In considering the anatomical planes of movement (frontal, sagittal, and transverse), there is an additional occlusal plane in terms of the teeth. The "occlusal plane" is defined as an imaginary surface that is related anatomically to the incisal edges of the incisors (the anterior portion of the bite) and tips of the occluding surfaces of the posterior teeth; it is not a plane in the true sense of the word, but it represents the mean of curvature of the surfaces of the teeth (Zwemer, 1982). Therefore, the position of the mandible is the dominant determining factor in the occlusal curvature of the teeth in that the mandible controls the placement of the lower teeth in the articulation with the upper teeth. Other contributing features include the height of each of the teeth and the neuromuscular controls of the mandible (Mohl, Zarb, Carlsson, & Rugh, 1988). It is also thought that tooth tilting, displacement, rotation, or supereruption as additional sources of the resulting occlusion (Abdel-Fattah, 2008).

Dental occlusion is normally classified into three classes: I, II, and III; these are divided based on the relation of the upper teeth to the lower teeth. Class I occlusion represents a normal relationship: all the teeth are perfectly placed in the arches of the jaws that have a normal anatomic relationship to each other (Zwemer, 1982). Class II occlusion represents a retruded relationship of the lower teeth to the upper ones, while class III occlusion is when there is a protrusive relationship of the lower teeth to the upper teeth (Abdel-Fattah, 2008). Class I arrangement conveys no discomfort or pain during functions that require articulation; manageable dissipation of forces are absorbed through the face, cranium, and mandible. In addition, stability is maintained throughout the production of these forces (Abdel-Fattah, 2008).

In terms of occlusion, when there is a deviation in the intramaxillary and/or intermaxillary relation of teeth, causing a potential hazard to the individual’s well being, it is referred to as *malocclusion* (Zwemer, 1982). Symptoms and signs of TMD are often associated with malocclusion; the TMJ becomes overloaded with a malocclusal bite (Abdel-Fattah, 2008). A strong correlation has been reported between malocclusion and TMD (Sonnesen, Bakke, & Solow, 1998).

Objectives of Occlusal Adjustment

There are four fundamental mechanical objectives when adjusting the occlusion of the TMJ: first, there must be an emphasis on the axial loading of the teeth in order to diminish the destructive horizontal forces; vertical forces are much more tolerable than horizontal forces. Second, a stable and adjusted position must be established with the terminal arc of closure (the posterior teeth). Third, there should be freedom of movement for the mandible in that a tooth or the cusp of a tooth should impede no movement. Lastly, the occlusal vertical dimension (meaning the opening and closing of the mouth) must be given an adequate amount of freeway space to provide normal function (Abrams, 1981).

Intraoral Orthotics

Intraoral orthotics are essentially occlusal appliances. There are two basic categories of occlusal appliances: permissive splints and directive splints (Dawson, 1988). A permissive splint provides a smooth, flat surface that permits uninhabited muscle positioning of the mandible. The positioning of the mandible may or may not represent a favorably oriented muscular position; a deviated position of the mandible is usually tolerated, however, because of the accommodation of it by the surrounding musculature (Wiygul, 1991). On the other hand, if a permissive splint repositions the mandible in such a way that it is imbalanced, a reciprocal imbalance of the neck and shoulder musculature will also occur (Wiygul, 1991).

A directive splint is a type of repositioning appliance that positions the mandible in a specific relationship to the maxilla, further determining where the condyles are located in this splint position. A splint that provides any guidance at all is considered a directive splint (Wiygul, 1991). Examples of such a splint are the Mandibular Orthopedic Repositioning Appliance (MORA), custom mouthguards, and boil-and-bite mouthguards. Because of their need to create a mold to the teeth, directive splints tend to be relatively more expensive than permissive splints; where permissive splints can be purchased for $1 at a sporting goods store, a MORA can cost anywhere from $300 to $800 (Yates, Koen, Semenick, & Kuftinec, 1984). Therefore, the price of the splint or orthotic is often considered by those utilizing oral appliances.

Several studies found in the literature have attempted to use a placebo appliance in order to measure results against as the control group portion of the study. However, it is difficult to construct such an appliance because of the fact that any appliance or material inserted between the teeth will ultimately change the articulation between the teeth, whether it may be the distance in between the upper and lower arches or the material properties of the appliance altering the way the upper and lower teeth interact with one another.

History of Mouthguard use in Sporting Activities

Historically, boxing as the first sporting activity to use mouthguards; these were fabricated from cotton, tape, sponge, or small pieces of wood. The purpose of these materials was to provide some sort of shock absorption from the blows to the face (Knapik et al., 2007). However, these materials were eventually banned from the sport due to instances where they were dislodged from the teeth and entered the larynx (Reed, 1994). The banning of mouthguards in boxing is also attributed to the time when the first reusable mouthguard was created for Ted Lewis during the 1920s and 1930s; his opponent complained about Lewis' use of a mouthguard and officials ruled the mouthpiece as forbidden because it was not permitted according to the rules of the game (Knapik et al., 2007). However, in 1927, boxing officials began to allow boxer's to use mouthguards due to an instance in one fight were a boxer's mouth was so severely injured that the fight had to be stopped (Jacobs, 1938).

The next sport to adopt the use of mouthguards was football; the main reasoning behind this was due to a high number of chipped or fractured teeth in the sport, accounting for 23-54% of all football injuries in the 1940s and 1950s (Knapik et al., 2007). In 1973, the National Collegiate Athletic Association (NCAA) mandated the use of mouthpieces that are of any color besides white or transparent and those that cover all of the upper teeth for players of college football (Adams, 2004). The American Dental Association currently recommend that mouthguards be used in 29 different sport or exercise activities, including basketball, soccer, and volleyball (American Dental Association, 2004).

Recent history shows that boil-and-bite mouthguards are the most popular mouthguards amongst collegiate level athletes (Padilla, 2006). However, it should be noted that research has been conducted assessing whether or not these mouth-formed mouthguards meet the rules of the NCAA. Kuebker, Morrow, and Cohen (1986) found that for a significant number of football players of the collegiate level, a typical boil-and-bite mouthguard was not large enough to meet the rules of the NCAA, due to a difference in the arch length (of the maxilla) in the population of African American athletes. In this case, the arch length was determined to be significantly larger than a population of racially mixed athletes. This study concluded that even the largest boil-and-bite mouthguard only met the NCAA rules for only 5.5 percent of African American football players.

Physical Properties of Mouthguards

Mouthguards purchased over-the-counter are typically a form of a permissive splint; this is mostly due to the fact that they are not custom-fitted to the athlete’s mouth (the exception is the boil-and-bite type of mouthguard, which will not be evaluated in this study). Mouthguards as athletic mouth protectors; their goal is to prevent teeth from injuring the soft tissues. When properly made, mouthguards do not contribute to occlusal dysfunction, and they may prevent injury during contact sports (Ash & Ramfjord, 1995).

In the past, a single sheet of soft material, most of the time a soft acrylic or vinyl, was used to create a mouthguard; however, because of the uniform thickness, torque was generated by attempts to make contact with the anterior teeth (i.e., the upper and lower posterior teeth could make contact with one another, but the upper and lower anterior teeth could not). Athletes would often cut off the molar (posterior) areas of the mouthguard in order to solve this problem, although this solution was not satisfactory. Instead, an extra strip of material should be used to support the posterior portion of the teeth (from one maxillary first molar to the other maxillary first molar) (Ash & Ramfjord, 1995).

The physical properties of a mouthguard include shock absorbing capabilities, hardness, stiffness, tear strength, tensile strength, and water absorption (Knapik et al., 2007). To define these properties in terms of a mouthguard is helpful into understanding the role of the appliance. The *shock absorbing capability* is the ability to reduce the impact energy or force transmitted to the surface beneath the mouthguard or material; *hardness* is the resistance of a material to penetration with a load applied; *stiffness* is the resistance of a material to deflection by an applied force; *tear strength* is a measure of the ability of a material to resist tear forces; *tensile strength* is the pull force required to break a material of a specific size; and *water absorption* is the amount of water taken up by a material (Knapik et al., 2007). Shock absorption, hardness and stiffness are generally indicative of the protective capabilities of the mouthguard, while tensile strength and shear strength are for durability; water absorption is necessary for the stability of the mouthguard when in an aqueous environment of the mouth (Going, Loehman, & Chan, 1974).

Impacts of Occlusal Orthotics on Physiological Capabilities of Athletes

Because athletic performance ultimately has a foundation in the physiological adaptations of muscles, understanding past research concerning this subject is pertinent. This is because of the differences found in muscles that have the capabilities to perform in a contrasting fashion. Type I muscle fibers are “slow twitch” or red muscle; these fibers allow for slower contractions, a longer time to fatigue, and less power, therefore contributing to endurance abilities. On the other hand, Type II muscle fibers are “fast twitch” or white muscle; these fibers allow faster contractions, and more power, but fatigue relatively quickly, and contribute to the burst of power an athlete attains (Guyton & Hall, 2006). Therefore, the field of exercise physiology utilizes a wide variety of testing methods in order to assess the capabilities of the athlete from an internal point of view. Applying mouthguards – a biomechanical intervention – to this equation, is therefore, very interesting.

In terms of actual results in athletic matches, adaptations of mouthguard use were examined by Gangloff (2000). By using a variety of interocclusal splints, it was found that postural control and gaze stabilization quality were affected. When the teeth were adjusted in a malocclusive manner, performance decreased; when the teeth were adjusted in a way that improved the occlusion, performance increased. Shooters had superior control with increased performance. The author concluded that proprioception and visual stabilization can be attributed to the utilization of a mouthguard.

In 1991, Francis and Brasher examined the physiological effects of wearing mouthguards. Here, they measured the ventilatory and gas exchange effects (via forced expiratory volume and peak expiratory flow rates) in ten healthy men and seven women.

By having these subjects serve as their own control group and conducting trials with and without three different types of over-the-counter mouthguards, they concluded that, although mouthguards may be perceptibly uncomfortable and further restrict forced expiratory flow, they are beneficial in prolonging exercise by improving the athlete’s ventilation and economy of energy.

Contrastingly, Delaney examined the impacts of a bimolar mouthguard on peak ventilation in ice hockey players (2005). He found that, when testing expired, ventilation and oxygen uptake in 12 varsity college female hockey players (where they skated on a treadmill), there was reduced ventilation and oxygen uptake at maximal efforts.

More recently Bourdin et al. tested 19 male athletes’ reaction time, explosive power, ventilation at rest, and ventilation and oxygen consumption during submaximal and maximal exercise (2006). Three bite conditions were tested: a control with no mouthguard use, a self-adapted mouthguard (boil-and-bite) that covered the maxillary arch, and a custom-made mouthguard that covered the maxillary arch. The study found that wearing a mouthguard does not affect the main physiological parameters associated with athletic performance in sport.

Oral Appliance use to Increase Biomechanical Strength

Studies regarding the repositioning of the mandible in aims to increase strength have evaluated the effectiveness of different types of oral appliances. There have been mixed results as to whether or not the use of oral appliances has an effect on muscular strength. It is fairly difficult to establish objective tests to determine the true effects of the use of oral appliances for strength augmentation in athletes; this is because most of the information available is subjective in nature, inviting much criticism from proponents of more traditional research designs (Aloi, 1991). These studies include those that found negative findings with the use of a MORA, that which found positive findings with the use of a MORA, that which used a wax bite to test muscular strength, and those that found positive findings with the use of a mouthguard; they are described as follows. Additionally, it should be noted that a placebo appliance – used by many studies found in the literature – is not necessarily an appropriate testing device. A placebo appliance will inevitably change the bite, either because of the difference caused by the thickness of the mouthpiece or because of the material and its effects on the articulation between the upper and lower teeth.

Because of the increased popularity of MORA use in athletics, many studies aimed to test whether or not the claims of its ability to increase the wearer's strength were true. In 1981, Greenberg, Cohen, Springer, Kotwick, and Vegso found that the use of a MORA did not enhance strength when comparing groups who used a MORA versus those who used a placebo when performing upper body strength exercises; all subjects were considered to have normal occlusion in this study. Burkett and Bernstein, in 1982, also could not find significant differences between a placebo splint and a MORA in their subjects. In both of these studies, there was no mention of excluding subjects with TMJ disorders. Also, there was no break period between the fitting of the splints and the test itself. In addition, subjects were tested with either a MORA or a placebo appliance, not both (i.e., they were placed into two different testing groups, and these tests were not crossed-over).

In 1984, Yates et al. attempted to improve the amount of control established by the previously mentioned studies when they experimented on the effects of a MORA on muscular strength in fourteen members of the University of Louisville football team; although dental examinations were performed on each of the subjects to determine the presence of TMJ dysfunction, no athlete was excluded due to the possession of any of the considered TMD symptoms (pain on opening or closing, clicking or popping, grinding noises, limited opening, locking opening, extreme sensitivity of the muscles operating the TMJ, headache, dizziness, or earache). They tested subjects in three different conditions: a control (no appliance), a placebo appliance (an orthodontic retainer), and a custom-fitted MORA for each athlete. The athletes were required to perform three different strength tests including an isometric dead lift, an isometric two-arm pull, and an isokinetic upright rowing movement. The researchers found that there was no significant difference in muscular strength between the control and the two types of appliances in the three testing conditions. Another study that carried through with the attempt to control for individual variability of subjects with TMJ disorders was performed by Allen, Walter, McKay, and Elmajian in 1984. In fact, all of the subjects they tested were chosen for the fact that they had TMJ symptoms. Each subject served as his or her own control in that cross-over was performed; the participants each performed muscle strength tests in all testing conditions: no splint, a placebo, and a MORA. Using a Cybex II isokinetic dynamometer, the maximum strength of the quadriceps, hamstrings, biceps, and triceps were measured. In all muscle groups tested, there was no significant difference in the strength under the three conditions. A third study used a double-blind format to determine whether or not TMJ repositioning had an effect on exercise performance using a MORA, a placebo, and no appliance as the testing conditions. As in the study by Allen et al., all of the subjects displayed symptoms of TMD. In the strength-testing portion of their study, in 1984 McArdle et al. evaluated muscular strength using a handgrip dynamometer and an adjustable dynamometer to measure elbow flexion strength and leg extension strength. In no case was there a significant difference in the testing variables.

One study found in the literature determined a significant difference in strength tests by the use of a MORA (Verban, Groppel, Pfautsch, & Ramseyer, 1984). The same conditions found in previous studies (no splint, placebo, and MORA) were used. Using a Cybex II dynamometer, significant differences in shoulder strength including shoulder extension (peak torque), shoulder extension (average torque), and external rotation (average torque). No significant differences were found between the placebo and the condition where no splint was used. The study concluded that there were significant improvements in shoulder strength by the use of a MORA.

In a study whose efforts were to obtain objective evidence that body muscular strength is correlated to posture and condition of the jaw, the creation wax bites for the ideal occlusal position for professional football subjects was the methodology utilized (Smith, 1978). At first, the author compared positions of the usual bite of the subjects with the new position (using the wax bites) in tests of resistance strength of the forearm. A significant difference of the arm’s ability to resist downward movements between the two testing conditions was found. In the same study, further testing of the subjects’ strength using a Cybex II dynamometer was conducted; a correlation was found to be positive for the use of wax bites to position the jaw in order to increase muscular strength.

In 1978, Stenger, Ricketts, Lawton, and Wright worked with the Philadelphia Eagles football team and examined the effects of kinesiologically adjusting the players' mouthguards. This study found that by posturing the players' jaws with a fitted wax bite instead of the regular stock mouthguard that the players normally used, that arm test musculature strength could be improved. In a continuation of their study in 1982, Stenger, Rickets, Lawton, and Wright established that the essential way to improve strength in the arm muscle tests was to "combine maximum bilateral molar support with lessened incisal (anterior) area mouthguard contact in the bites evaluated."

A large amount of time difference takes place between the previous research and the most recent available research on mouthguards. Contrasting the various studies of the 1980s and the more modern examinations of mouthguards in the biomechanical aspect, the newer studies tend to incorporate a more dynamic point of view. The research of Cetin, Keçeci, Erdoğan, and Baydar (2009) displays this. Using 21 trained taekwondo athletes, they examined both biomechanical and physiological effects of mouthguard use, although the latter was much more emphasized in their study. They determined anaerobic power and anaerobic capacity, 20 m sprint time, squat and countermovement jumping height, as well as isometric and isokinetic muscle strength tests, with and without custom made mouthguards. For the 20 m sprint, jumping tests, and isometric tests, they found no significant difference between the groups. For the anaerobic and isokinetic tests, however, the study found a significant increase as the result of wearing a mouthguard.

It is with this literature that this study will attempt to build on in order to gain more information on the use of non-custom mouthguards and their effects on muscular strength. Although there is obviously literature available on such a subject, this further examination is necessary for several reasons. For one most of these experiments used subjects without distinguishing between those with TMD and those without. Additionally, these experiments have assumed that all appliances contained within one subject category (i.e., MORA or maxillary mouthguard) are equivalent; in no instance was the manufacturing of the custom made mouthguard delineated. Therefore, it may be that this process was not tightly controlled (i.e., the heating time of the acrylic sheet before it is molded to the model of the arch). Lastly, several of these experiments employed the use of a placebo; in reality, using a placebo in terms of an oral orthotic is difficult and virtually impossible. Any material placed between the teeth will ultimately alter the occlusion, therefore having some effect on the bite and therefore investigational results. In conclusion, the lack of control over such examples may explain the wide variety of results found in the literature.

CHAPTER III: METHODS

Participants

The purpose of this study is to determine the effects of two different types of over-the-counter, non-custom mouthguards – upper mouthguards and double mouthguards – on isokinetic muscular strength performance and vertical jump height in collegiate level athletes. Upon approval of the Institutional Review Board of Barry University, 26 male and female athletes who were each members of a Barry University athletic team volunteered for the study after contact with the team coaches and athletic trainers (verbally); in addition, word-of-mouth was used.

A written informed consent (Appendix A) was a required completion by all participants. This consent notified participants of the experimental procedures, purpose, time requirements and the possible risks and benefits of participating. Subject names and test results were kept separate during and after the study. Once all subjects agreed to voluntary participation in the study, appointments were made with them for data collection, based on the availability of the participant and the availability of the researcher. The participants were informed to wear athletic type clothing and shoes as they would during a game or practice, with the exception of any additional or protective gear they may typically wear (shin guards, cleats, knee pads).

In that the study called for subjects who did not have any history of Temporomandibular Joint Disorder (TMD), a Subject Profile Questionnaire (Appendix B) was a required completion by all 26 volunteers. This was done in order to differentiate any subjects who do not possess these requirements. In the completion of this questionnaire, two athletes were not approved for data collection (one athlete was diagnosed with TMD by her dentist, while the other athlete explained that she had popping and irregular movement of the jaw, as well as clicking of the jaw, which are symptoms of TMD). Therefore, 24 athletes were permitted to proceed to participate in the data collection for this study.

Instrumentation

The Biodex System 3 Dynamometer was used for isokinetic strength testing of knee flexion and extension, as well as shoulder external and internal rotation, with the two joints having been tested on the same day. The Biodex System 3 is a self-calibrating machine. The Biodex System 3 is considered to measure strength with acceptable mechanical reliability and validity at all speeds except those that are 300 degrees per second or higher for all variable types (Drouin, Valovich-McLeod, Shultz, Gansneder, & Perrin, 2004). The protocols used by the Biodex System 3 were the following:

- Isokinetic knee flexion/extension with con/con 60/60: the muscles of the knee isokinetically contract concentrically during flexion, and contract concentrically during extension, with both movements occurring at 60 degrees per second.
- Isokinetic knee flexion/extension with con/con 180/180: the muscles of the knee isokinetically contract concentrically during flexion, and contract concentrically during extension, with both movements occurring at 180 degrees per second.
- Isokinetic shoulder internal/external rotation test with con/con 60/60 modified neutral: the muscles of the shoulder isokinetically contract concentrically during external rotation, and contract concentrically during internal rotation, with both movements occurring at 60 degrees per second.

- Isokinetic shoulder internal/external rotation test with con/con 180/180 modified neutral: the muscles of the shoulder isokinetically contract concentrically during external rotation, and contract concentrically during internal rotation, with both movements occurring at 180 degrees per second.

For each participant, the range of motion was first taken for each joint at the different speeds; this was done by having the full extension and full flexion of the knee recorded by the dynamometer before the sets began, as well as full external rotation and full internal rotation of the shoulder. Therefore, two knee movements, flexion and extension, and two shoulder movements, internal and external rotation, were examined in six sets of five repetitions each. The six sets were each divided into first and second halves, in order to discriminate between the sets in which the mouthguards were used (see Table 1). Each of the subjects performed the movements while strapped into the dynamometer. The repetitions required that the subjects moved through the full available range of motion while in the chair and that the participants completed the exercises to the best of their abilities. One minute of rest was allowed between trials, and knee and shoulder tests will be done on the same day. The 60-degree per second and 180-degree per second modules will be given in a randomized fashion.

Force production was measured as foot-pounds (ft-lbs) and Joules (J) as produced by the dynamometer, via the measurements of “Peak Torque” and “Total Work” for each set, respectively. These values of peak torque and total work that were found in each of the sets were used to compare strength differences among the sets and the groups; the knee and shoulder were analyzed separately, as well as the speeds. The participants were each tested by the same tester in the six sets of the knee and the six sets of the shoulder. It was forbidden for the participant to move from the Biodex chair between sets for the same joint in order to ensure all settings on the Biodex remained the same.

Subjects were informed that the Biodex testing process required straps tight across the chest, waist, thigh, and leg. The participants were first properly positioned on the Biodex System 3 by the tester. For the knee exercises, the settings for the apparatus were the following:

- Chair - 90°
- Dynamometer - 90°
- Dynamometer Tilt - 0°

For the shoulder exercises, the settings for the Biodex System 3 were the following:

- Chair - 0°
- Dynamometer - 20°
- Dynamometer Tilt - 50°

A preliminary set was performed to allow the subjects to accommodate the speed at which the testing was done. The test began with the subject holding the knee in full flexion for the knee test, while for the shoulder test it was held in full external rotation; these positions prompted the Biodex System to begin the sets.

The examination of vertical jump height was assessed after the completion of the muscle strength tests. For this test, the Vertec vertical jump height testing apparatus was used. Subjects stood directly under the Vertec device and conducted 6 vertical squat jumps to their maximum ability, leaving and landing on the ground with two feet. The

Vertec has been shown to be a valid and reliable apparatus when used in the following manner: first, the standing height of the subject with one arm fully extended upward was taken. Then, the subject jumped up and touched the highest possible vane. The difference between standing height and jumping height was then measured (Hutchinson & Stone, 2009).

The upper mouthguard that was used was the *All Sport Master Strapless Mouth Guard* made by Fox 40 International, Inc. The double mouthguard that was used was the *Double Mouth Piece* manufactured by Macho Martial Arts. Both of the mouthguard models were non-custom, stock mouthguards.

Test results used for the data analysis were kept in a cabinet in the researcher's home throughout the remainder of the study. The Data Collection Forms (Appendix C) were be completed by the tester for each participant, listing the data acquired from each subject in accordance with the subject numbers that were assigned to them at the start of the procedure.

Procedures

Twenty-six volunteer athletes participated in this study. Volunteers were first instructed to complete the Informed Consent (Appendix A). Then, the Subject Profile Questionnaire (Appendix B) was completed, in order to eliminate any subject that did not meet the requirements of the study. Subjects were assigned participant identification numbers on the Subject Profile Questionnaire form, and were thenceforth referred to only by their subject numbers for the remainder of the study. Of the 26 volunteers, 24 participants qualified for the study and were placed into four randomized groups as reflected by the order in which they sign up for the study. The order in which each person signed up for the study determined which group he or she belonged to; the first participant was placed into group 1, the second participant was placed into group 2, the third participant was placed into group 3, and the fourth participant was put into group 4; participant 5 began this placement cycle over, meaning he or she was placed into group 1, and so forth. The volunteers were told the available times of the researcher, and each participant made an appointment based on these times for data collection, for both the knee tests and the shoulder tests. The expected time commitment of the participant was expected to be 1 hour.

Upon arrival, the participant’s height and weight was recorded on their data collection sheet (data collection sheets indicated the subject’s participant identification number). First, the subject sat down on the chair of the Biodex apparatus and the machine was adjusted to their fitting, according to the settings for each joint. The subjects were each told that they were to conduct six sets of the isokinetic strength tests on four separate occasions, with rest periods in between the sets. The order of the tests for all subjects were randomized and consisted of the following: knee flexion/extension at 60 degrees per second, knee flexion/extension at 180 degrees per second, shoulder external/internal rotation at 60 degrees per second, shoulder external/internal rotation at 180 degrees per second. The strength tests were followed by the vertical squat jump test. The four randomized groups underwent four different ordering of the sets (in both the knee and shoulder tests) in order to control for fatigue effects; in addition, two of the groups used the upper mouthguard, while the other two groups used the double mouthguard (see Table 1).

Before the sets were conducted, the tester showed the mouthguard to the participant in its sealed package, meaning the mouthguard was brand new for each participant and no mouthguards were reused. A sealable plastic bag with the participant’s identification number written in permanent marker was created for each participant, as the mouthguards were stored inside the bags between uses. The same model number of mouthguard for both the upper and the double mouthguards were used for each and every participant.

After the Biodex was adjusted to the subject’s comfort, the chest, thigh, and leg straps were then fastened across the subject’s respective body parts (see Figures 1 and 2). Subjects performed a preliminary strength test set of five repetitions on the Biodex, once before the two knee tests, and once before the two shoulder tests; these preliminary exercises were performed in order to correct form and explain the proper execution of the exercises. When the subject aware of the correct form and proper execution of the exercise, the first set began.

Figure 1. Proper set up of Biodex System 3 dynamometer for the knee exercises.


[redacted]

Figure 2. Proper set up of Biodex System 3 dynamometer for the shoulder exercises.

For the vertical jump test, the subject first had his or her standing height with one arm fully extended upward taken (see Figure 3).


[redacted]

Figure 3. Vertical jump initial measurement.

The subject then, from a squatting position, jumped off the ground with two feet and touched the highest possible vane (see Figure 4).

Figure 4. Take-off for the vertical jump test.

The difference between standing height and jumping height was then measured. This was repeated six times total, with the first three trials and last three trials differing in mouthguard use according to group assignment.

Trials and Design

Each participant underwent six sets of five repetitions each for both the shoulder and the knee, at each of the two speeds (60 degrees per second and 180 degrees per second) performed at each joint, as well as perform six jumps under the Vertec; in that the independent variable is bite condition (upper mouthguard or double mouthguard), this was the differing variable amongst groups, in addition to the order in which the sets were performed. The isokinetic muscle strength testing for the participants was indicative of the following table; all four tests were done on the same day. The word test indicates the four different tests of the knee at the two speeds and the shoulder at two speeds, in which each participant will perform all four tests.

The average of the peak torques and total works from sets one, two and three were compared to the average of the peak torques from each of sets four, five and six (peak torque is the data presented by the Biodex, individual peak torques are not provided for each repetition within a set). For the vertical jump trials, the average of the three trials with the mouthguard and the average of the three trials without the mouthguard was compared for each subject, and furthermore within and between groups. This measurement was made in centimeters. Therefore, comparisons both within groups and between groups will create the results that will be analyzed.

Table 1

Order of Isokinetic Testing Organized by Group

Group 1 (No Mouthguard/ Upper Mouthguard)	Group 2 (Upper Mouthguard/ No Mouthguard)	Group 3 (No Mouthguard/ Double Mouthguard)	Group 4 (Double Mouthguard/ No Mouthguard)
Set 1: No mouthguard	Set 1: Upper mouthguard	Set 1: No mouthguard	Set 1: Double mouthguard
1 minute rest	1 minute rest	1 minute rest	1 minute rest
Set 2: No mouthguard	Set 2: Upper mouthguard	Set 2: No mouthguard	Set 2: Double mouthguard
1 minute rest	1 minute rest	1 minute rest	1 minute rest
Set 3: No mouthguard	Set 3: Upper mouthguard	Set 3: No mouthguard	Set 3: Double mouthguard
1 minute rest	1 minute rest	1 minute rest	1 minute rest
Set 4: Upper mouthguard	Set 4: No mouthguard	Set 4: Double mouthguard	Set 4: No mouthguard
1 minute rest	1 minute rest	1 minute rest	1 minute rest
Set 5: Upper mouthguard	Set 5: No mouthguard	Set 5: Double mouthguard	Set 5: No mouthguard
1 minute rest	1 minute rest	1 minute rest	1 minute rest
Set 6: Upper mouthguard	Set 6: No mouthguard	Set 6: Double mouthguard	Set 6: No mouthguard

During the trials that used the mouthguards, the tester put on latex-free exam gloves and assisted in placing the mouthguard into the participant’s mouth. After the mouthguard sets, the appliance was placed in a sealable plastic bag assigned to the subject by the indicated participant identification number on the bag. To avoid confusion, only one bag and one mouthguard were allowed out at a time. The tester took off the exam gloves after each set that required the use of the mouthguard, and put on new gloves at the start of each mouthguard set.

The resulting peak torques and total works for each set was recorded in foot-pounds (ft-lbs.) and Joules, respectively, on the subject’s Data Collection Form.

Data Analysis

The data from each participant was entered into PASW Statistic 18.0 Software. In order to compare the isokinetic test results, the average of the sets using the mouthguard (either the first three sets or the last three sets) was compared to the other three sets that did not use the mouthguard (either the first three or last three sets). Using the software, the data was first screened and transformed, to ensure accuracy of the data. The following variables were compared: Peak Torque Away, Total Work Away, Peak Torque Towards, and Total Work Towards. The variables examined are elaborated in Table 2.

Therefore, 4 x 2 between-within mixed-design ANOVAs were completed for each dependent variable at each speed, for each joint. An additional 4 x 2 between-within mixed-design ANOVA was also done for jump height analysis. This allowed for the comparison of the changes between bite condition (mouthguard or no mouthguard) for each group, as well as a comparison amongst the four different groups.

Table 2

Dependent Variables

Test	Dependent Variables
Knee 60/60 and Knee 180/180	Peak torque away (extensors) with mouthguard Peak torque away (extensors) without mouthguard Total work away (extensors) with mouthguard Total work away (extensors) without mouthguard Peak torque towards (flexors) with mouthguard Peak torque towards (flexors) without mouthguard Total work towards (flexors) with mouthguard Total work towards (flexors) without mouthguard
Shoulder 60/60 and shoulder 180/180	Peak torque away (external rotators) with mouthguard Peak torque away (external rotators) without mouthguard Total work away (external rotators) with mouthguard Total work away (external rotators) without mouthguard Peak torque towards (internal rotators) with mouthguard Peak torque towards (internal rotators) without mouthguard Total work towards (internal rotators) with mouthguard Total work towards (internal rotators) without mouthguard
Jump Height	Vertical jump with mouthguard Vertical jump without mouthguard

CHAPTER IV: RESULTS

The purpose of this study was to determine the effects of non-custom mouthguards on repeated muscular strength tests and vertical jump height in collegiate-level athletes. The specific purpose was to compare the effect of bite conditions – with mouthguard use and without mouthguard use, as well as varying mouthguard types (double mouthguard and upper mouthguard) on the dependent variables of Peak Torque and Total Work of the muscles that extend and flex the knee and those that externally and internally rotate the shoulder. These variables were each measured at two different speeds, 60 degrees per second and 180 degrees per second. In addition, a functional application was considered in comparing jump heights for the different bite conditions and mouthguard types.

Eight males and 16 females served as participants approved to take part in the study. All participants were experienced athletes and members of a varsity team at Barry University, each having at least five years of experience within their respective sport. The athletes came from several different intercollegiate sports teams, including soccer (7 athletes), baseball (5), basketball (5), softball (2), volleyball (2), rowing (2), and golf (1). In that amount of volunteers totaled to 24, the groups each consisted of 6 subjects. 4 x 2 between-within mixed-design ANOVAs were completed for each dependent variable at each speed, for each joint. An additional 4 x 2 between-within mixed-design ANOVA was also done for jump height analysis. This allowed for comparison between groups and within groups, in that comparing within a group entails comparing the sets in which the mouthguard was not used and those in which it was used. Again, the data is organized by test performed on the Biodex Dynamometer, followed by the jump height analysis. Descriptive Statistics for each test type is found in Appendix D.

Comparisons Between and Within Groups

Isokinetic Knee Flexion/Extension with Con/Con 60/60

Peak Torque Away (Extension): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group (groups 1, 2, 3, and 4) and bite condition (no mouthguard and mouthguard) on peak torque away at 60 degrees per second for the knee. A significant relationship was found between group and bite condition for the peak torque values (*F*(3,20) = 3.239, p < .05). In addition, the main effect for bite condition was also significant (*F*(1,20) = 7.716, p < .05). The main effect for group was not significant (*F*(3,20) = 0.781, p > .05). Upon examination of the data, it appears that Groups 1 (upper mouthguard/no mouthguard), 2 (no mouthguard/upper mouthguard), and 3 (double mouthguard/no mouthguard) showed significant improvements when using the mouthguard. (Figure 5)

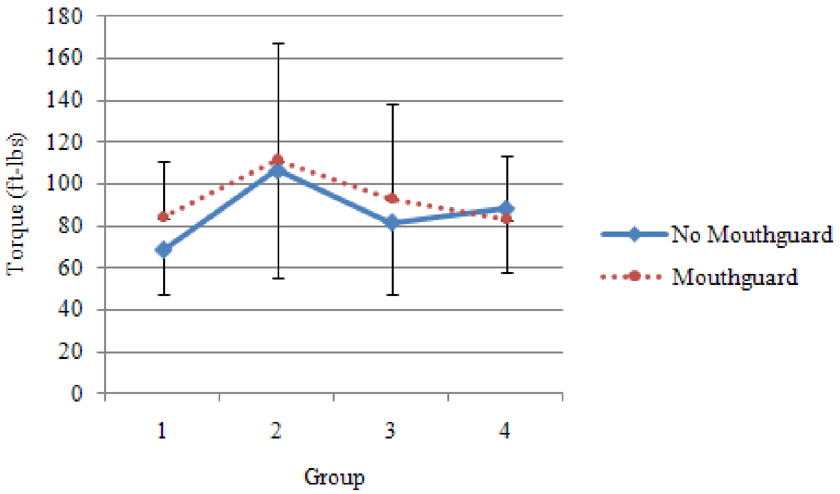

Figure 5. Peak Torque Away of the Knee at 60 deg/sec

Total Work Away (Extension): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on total work away at 60 degrees per second for the knee. The differences that were found between group and bite condition for the total work values was not significant (*F*(3,20) = 1.653 , p > .05). In addition, the main effect for bite condition was also not significant (*F*(1,20) = 1.252, p < .05). Lastly, the main effect for group was not significant (*F*(3,20) = 0.477, p > .05) (Figure 6).

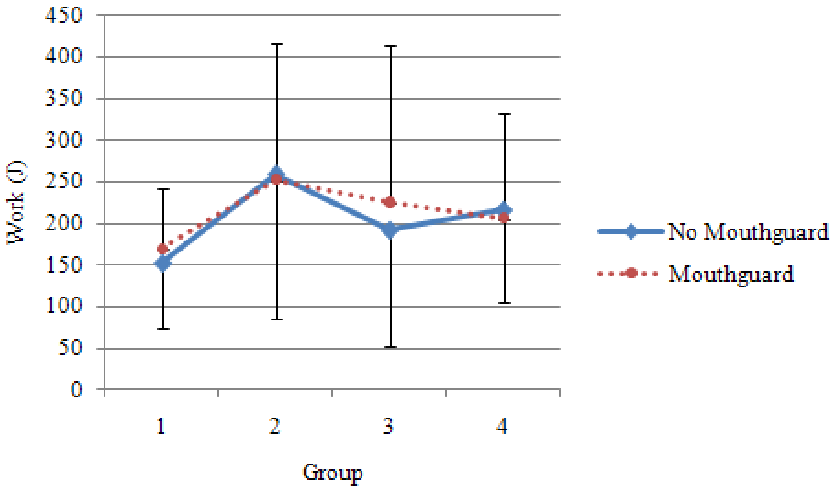

Figure 6. Total Work Away of the Knee at 60 deg/sec

Peak Torque Towards (Flexion): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on peak torque towards at 60 degrees per second for the knee. The differences that were found between group and bite condition for the peak torque values was not significant (*F*(3,20) = 2.864, p > .05). On the other hand, the main effect for bite condition was significant (*F*(1,20) = 7.059, p < .05). Additionally, the main effect for group was not significant (*F*(3,20) = 0.527, p > .05). Upon examination of the data, it appears that Groups 1, 2, and 3 showed significant improvements when using the mouthguard (Figure 7).

Total Work Towards (Flexion): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on total work towards at 60 degrees per second for the knee. The relationship that was found between group and bite condition for the total work values was not significant (*F*(3,20) = 2.133, p > .05). However, the main effect for bite condition was significant (*F*(1,20) = 8.510, p < .05). Additionally, the main effect for group was not significant (*F*(3,20) = 0.255, p > .05). Upon examination of the data, it appears that Groups 1, 2, and 3 showed significant improvements when using the mouthguard. (Figure 8)

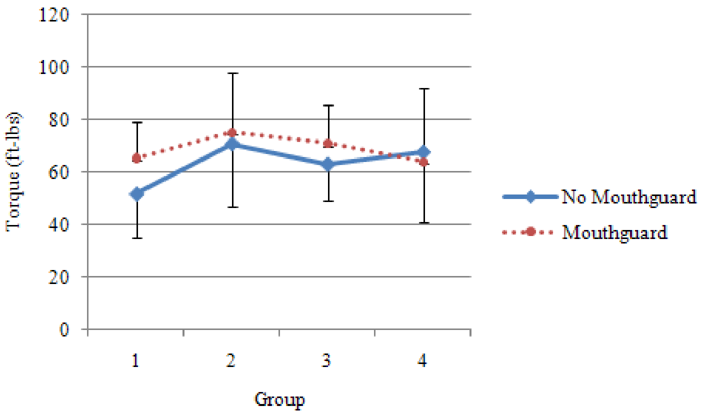

Figure 7. Peak Torque Towards of the Knee at 60 deg/sec

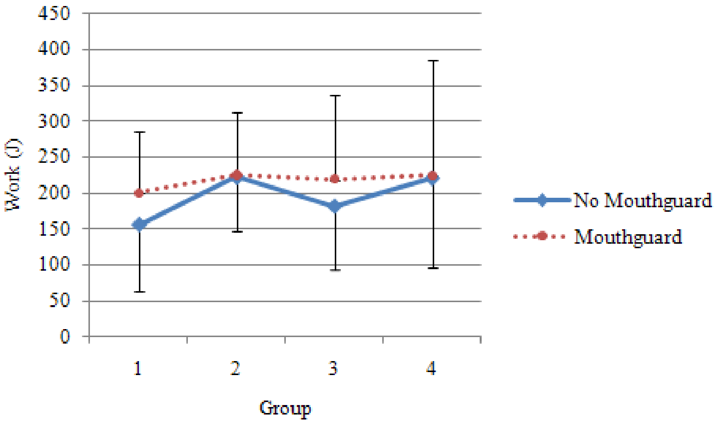

Figure 8. Total Work Towards of the Knee at 60 deg/sec

Isokinetic Knee Flexion/Extension with Con/Con 180/180

Peak Torque Away (Extension): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on peak torque away at 180 degrees per second for the knee. The interaction that was found between group and bite condition for the peak torque values was not significant (*F*(3,20) = 2.541, p > .05), meaning there was no significant differences between group and bite condition. The main effect for bite condition was significant (*F*(1,20) = 6.226, p < .05). The main effect for group was also not significant (*F*(3,20) = 0.226, p > .05). Upon examination of the data, it appears that Groups 1, 2, and 3 showed significant improvements when using the mouthguard. (Figure 9)

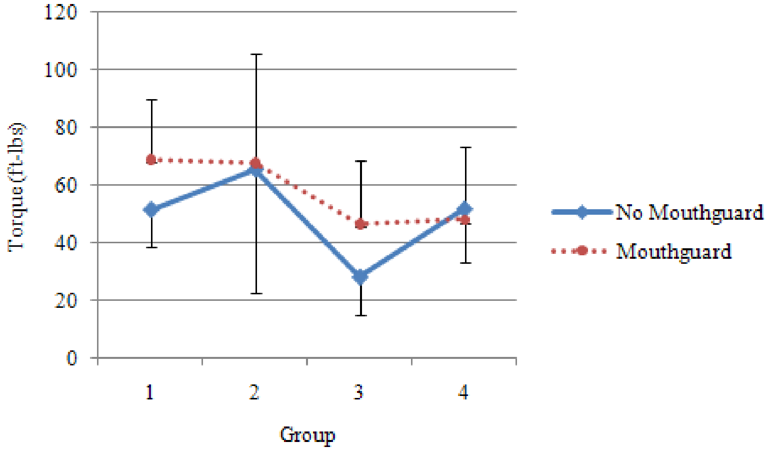

Figure 9. Peak Torque Away of the Knee at 180 deg/sec

Total Work Away (Extension): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on total work away at 180 degrees per second for the knee. The relationship that was found between group and bite condition was significant (*F*(3,20) = 3.375, p < .05). However, the main effect for bite condition was not significant ($F(1,20) = 2.834$, $p > .05$). The main effect for group was also not significant ($F(3,20) = 0.926$, $p > .05$). Upon examination of the data, it appears that Groups 1 and 2 had significant improvements with mouthguard use. (Figure 10)

Peak Torque Towards (Flexion): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on peak torque towards at 180 degrees per second for the knee. The relationship that was found between group and bite condition for the peak torque values was not significant ($F(3,20) = 0.605$, $p > .05$). On the other hand, the main effect for bite condition was significant ($F(1,20) = 5.667$, $p < .05$). Additionally, the main effect for group was not significant ($F(3,20) = 1.511$, $p > .05$). By looking at the data, one can see that Groups 1, 2, and 3 had significant improvements with mouthguard use. (Figure 11)

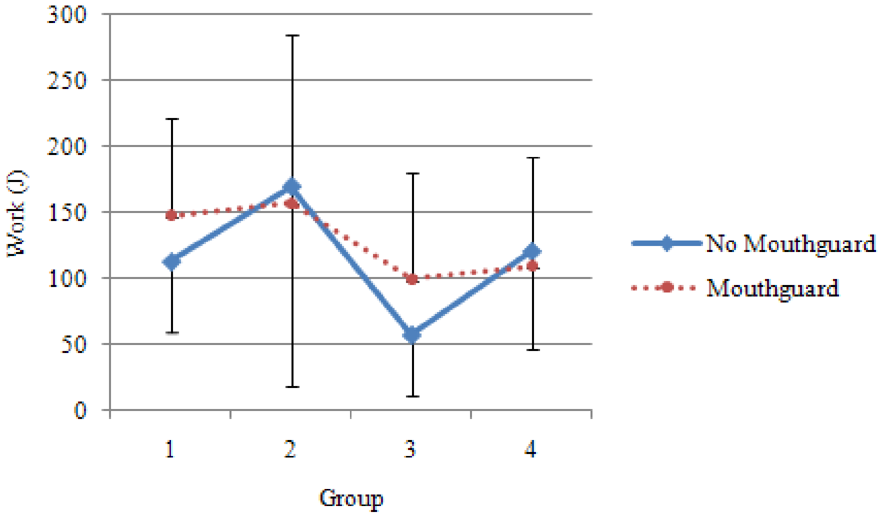

Figure 10. Total Work Away of the Knee at 180 deg/sec

Total Work Towards (Flexion): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on total work towards at 180 degrees per second for the knee. The relationship that was found between group and bite condition was not significant (*F*(3,20) = 1.107, p > .05). However, the main effect for bite condition was significant (*F*(1,20) = 5.344, p < .05). The main effect for group was also not significant either (*F*(3,20) = 0.581, p > .05). The data shows that Groups 1, 2, and 3 had improvements in strength with mouthguard use. (Figure 12)

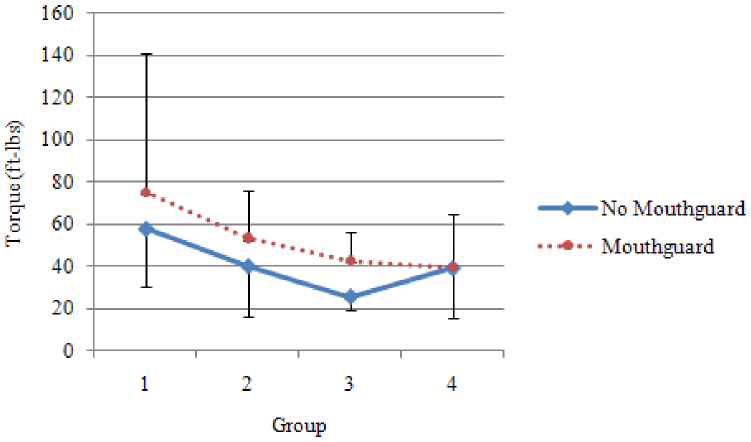

Figure 11. Peak Torque Towards of the Knee at 180 deg/sec

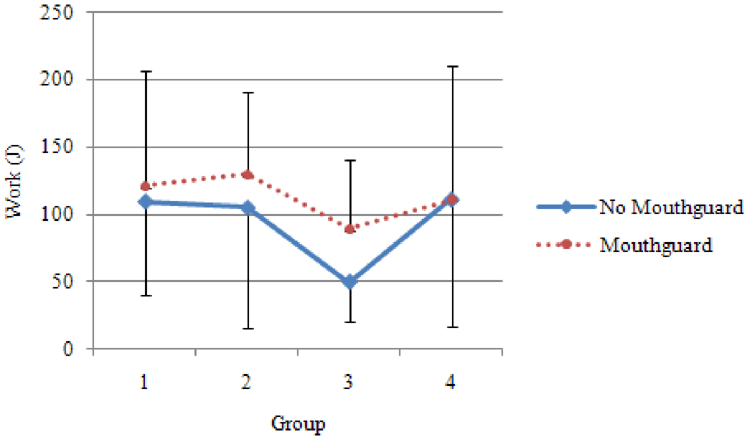

Figure 12. Total Work Towards of the Knee at 180 deg/sec

Isokinetic Shoulder Internal/External Rotation with Con/Con 60/60 Modified Neutral

Peak Torque Away (External Rotation): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on peak torque away at 60 degrees per second for the shoulder. The relationship between group and bite condition for the peak torque values was not significant (*F*(3,20) = .431, p > .05). The main effect for bite condition was also not significant (*F*(1,20) = .285, p > .05). Lastly, the main effect for group was also not significant (*F*(3,20) = 2.659, p > .05). The data produced indicates that Groups 1, 2, 3, and 4 did not show significant improvements when using the mouthguard. (Figure 13)

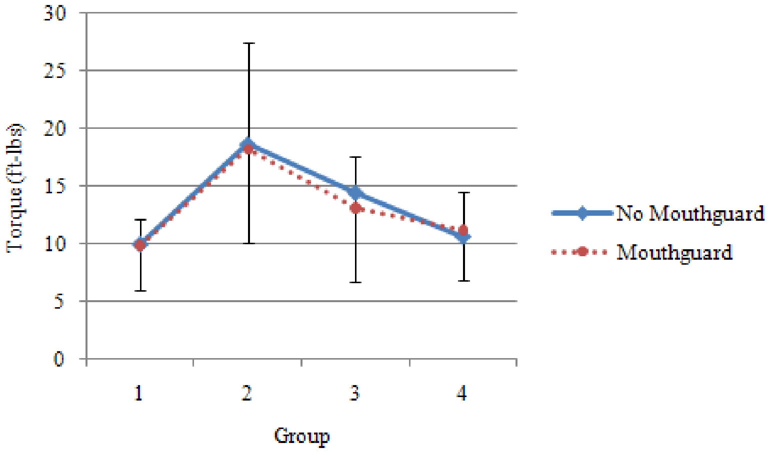

Figure 13. Peak Torque Away of the Shoulder at 60 deg/sec

Total Work Away (External Rotation): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on total work away at 60 degrees per second for the shoulder. The relationship between group and bite condition for the peak torque values was not significant (*F*(3,20) = .580, p > .05). The main effect for bite condition was also not significant (*F*(1,20) = .071, p > .05). Lastly, the main effect for group was also not significant (*F*(3,20) = .642, p > .05). (Figure 14)

Peak Torque Towards (Internal Rotation): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition peak torque towards at 60 degrees per second for the shoulder. The relationship between group and bite condition for the peak torque values was not significant (*F*(3,20) = .170, p > .05). The main effect for bite condition was also not significant (*F*(1,20) = 3.173, p > .05). Contrastingly, the main effect for group was significant (*F*(3,20) = 3.375, p < .05). Mouthguard use has no effect on the peak torque while internally rotating the shoulder at 60 degrees per second. (Figure 15)

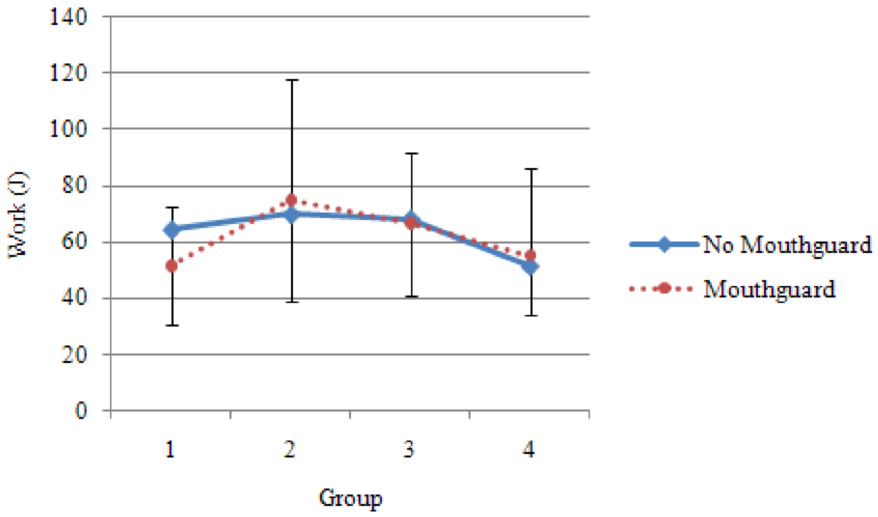

Figure 14. Total Work Away of the Shoulder at 60 deg/sec

Total Work Towards (Internal Rotation): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on total work towards at 60 degrees per second for the shoulder. The relationship between group and bite condition for the peak torque values was not significant (*F*(3,20) = .380, p > .05). The main effect for bite condition was also not significant (*F*(1,20) = 2.455, p > .05). Lastly, the main effect for group was also not significant (*F*(3,20) = 2.060, p > .05). (Figure 16)

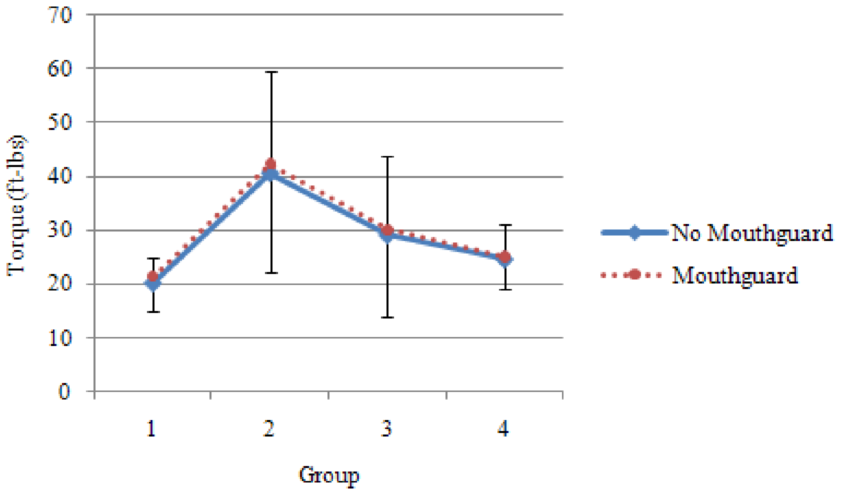

Figure 15. Peak Torque Towards of the Shoulder at 60 deg/sec

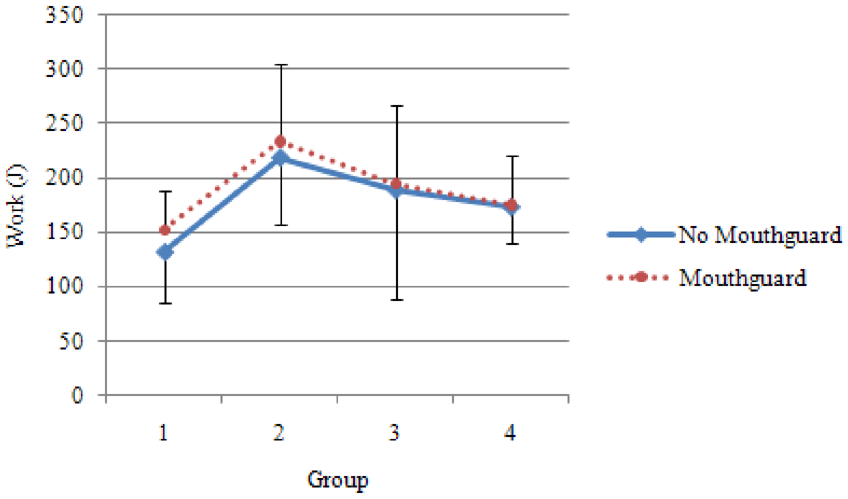

Figure 16. Total Work Towards of the Shoulder at 60 deg/sec

Isokinetic Shoulder Internal/External Rotation with Con/Con 180/180 Modified Neutral

Peak Torque Away (External Rotation): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on peak torque away at 180 degrees per second for the shoulder. The relationship between group and bite condition for the peak torque values was not significant (*F*(3,20) = 1.349, p > .05). The main effect for bite condition was also not significant (*F*(1,20) = 2.491, p > .05). Additionally, the main effect for group was also not significant (*F*(3,20) = .601, p > .05). (Figure 17)

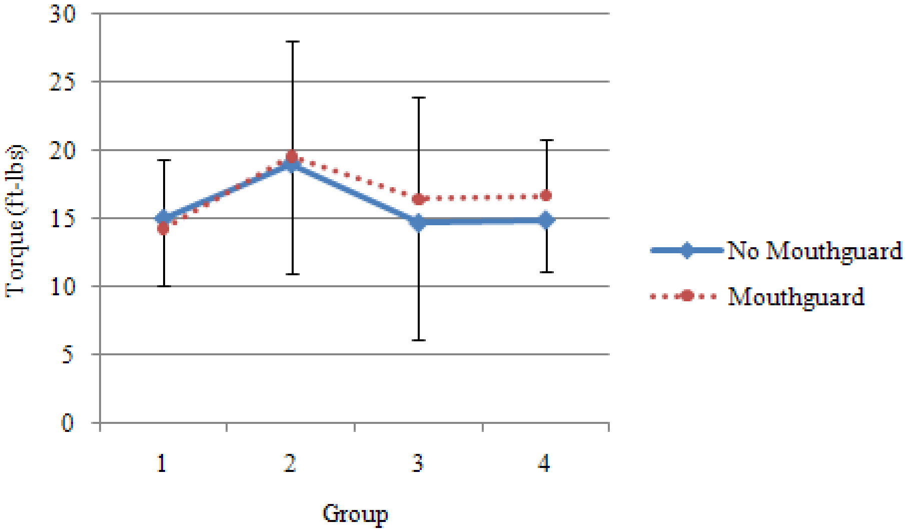

Figure 17. Peak Torque Away of the Shoulder at 180 deg/sec

Total Work Away (External Rotation): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on total work away at 180 degrees per second for the shoulder. The relationship between group and bite condition for the peak torque values was not significant (*F*(3,20) = .887, p > .05). The main effect for bite condition was also not significant (*F*(1,20) = .014, p > .05). Lastly, the main effect for group was also not significant (*F*(3,20) = .317, p > .05). (Figure 18)

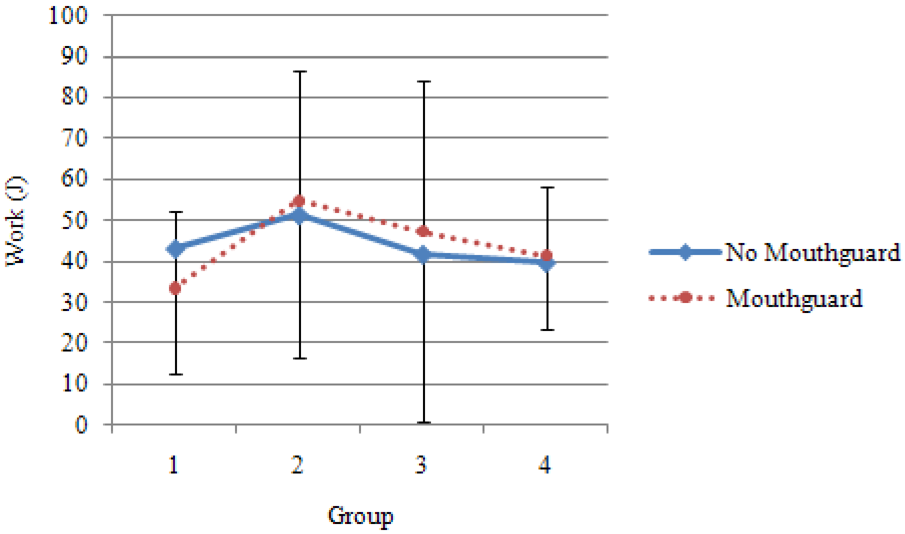

Figure 18. Total Work Away of the Shoulder at 180 deg/sec

Peak Torque Towards (Internal Rotation): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition peak torque towards at 180 degrees per second for the shoulder. The relationship between group and bite condition for the peak torque values was not significant (*F*(3,20) = 1.708, p > .05). The main effect for bite condition was also not significant (*F*(1,20) = 2.118, p > .05). The main effect for group was also not significant (*F*(3,20) = 2.562, p > .05). Mouthguard use has no effect on the peak torque while internally rotating the shoulder at 180 degrees per second. (Figure 19)

Total Work Towards (Internal Rotation): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on total work towards at 180 degrees per second for the shoulder. The relationship between group and bite condition for the peak torque values was not significant (*F*(3,20) = 1.448, p > .05). The main effect for bite condition was also not significant (*F*(1,20) = 1.342, p > .05). Lastly, the main effect for group was also not significant (*F*(3,20) = .653, p > .05). (Figure 20)

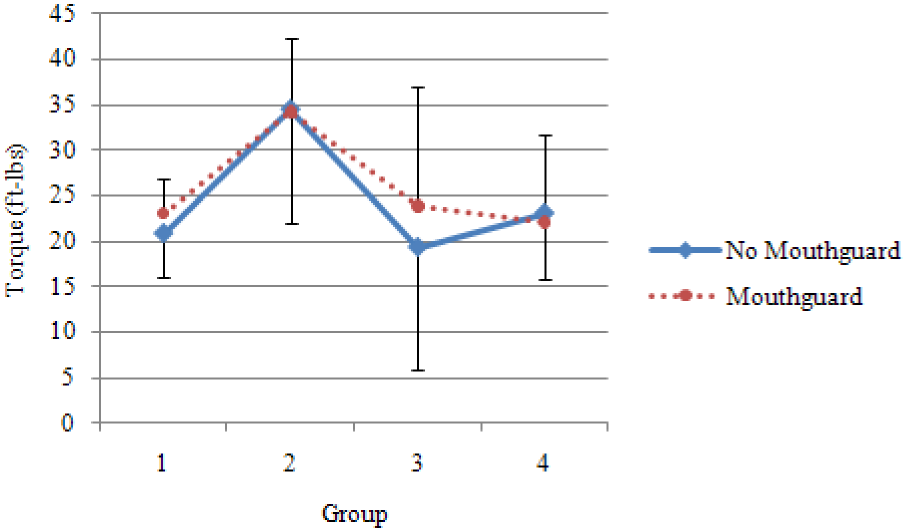

Figure 19. Peak Torque Towards of the Shoulder with Con/Con 180/180 Mod Neutral

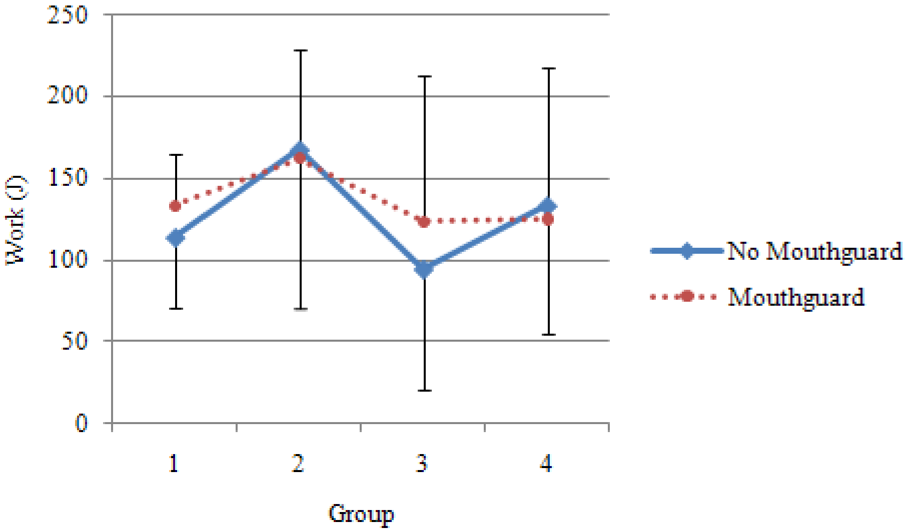

Figure 20. Total Work Towards of the Shoulder at 180 deg/sec

Jump Height Differential

A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on vertical jump height after performing a squat jump. The relationship between group and bite condition differential values was not significant (*F*(3,20) = 1.079, p > .05). However, both the main effect for bite condition (*F*(1,20) = 14.420, p < .05) and the main effect for group were significant (*F*(3,20) = 3.465, p < .05). Jump heights were on average improved with mouthguard use, but not enough to deem significant. (Figure 21)

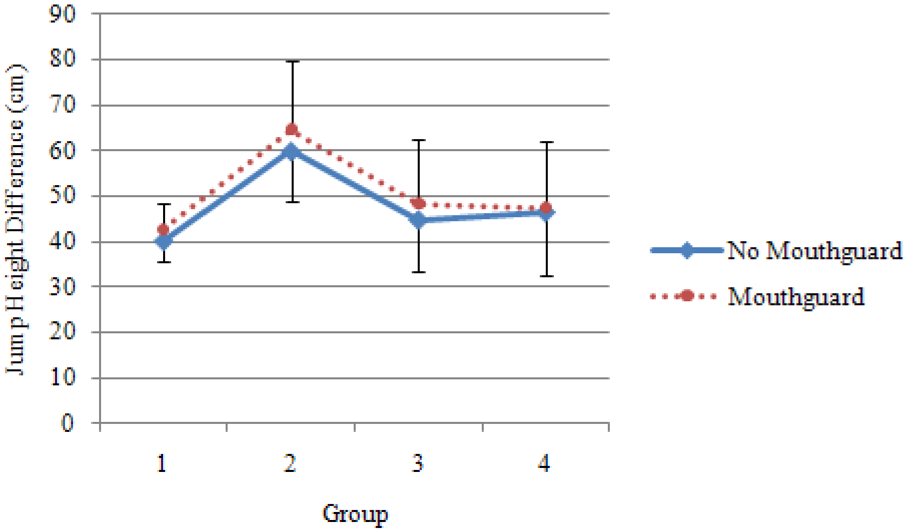

Figure 21. Jump Height Differentials Comparing Bite Conditions

CHAPTER V: DISCUSSION

The purpose of this study was to determine the impacts of non-custom mouthguards on muscular strength performance on the muscles that act on the knee joint during flexion and extension and the muscles that act on the shoulder joint during external and internal rotation. In addition, the idea of observing the effects of non-custom mouthguards towards a functional application – jump height – was also examined in this study. It was hypothesized that mouthguard use would significantly improve isokinetic muscular strength of each of the muscle group sets (knee flexors, knee extensors, shoulder external rotators, and shoulder internal rotators) both in terms of peak torque and total work. Additionally, it was hypothesized that utilizing mouthguards would significantly improve jump height when performing a vertical squat jump.

Summary of the Findings

Employing the use of the data collected and statistics produced by this study, the following conclusions may be made in our comparisons of the groups:

- The upper mouthguard significantly improved isokinetic muscle strength of the knee extensor muscles in collegiate level athletes in terms of peak torque at a speed of 60 degrees per second, but had no impact on any other variable at this speed. Additionally, the upper mouthguard significantly improved isokinetic muscle strength of the knee extensor muscles in collegiate level athletes in terms of total work at 180 degrees per second, but had no significant effects on any other variable at this speed.

- The upper mouthguard did not significantly improve isokinetic muscle strength of the shoulder external rotator muscles in collegiate level athletes in terms of both peak torque and total work, at either speed that was tested.
- The upper mouthguard did not significantly improve isokinetic muscle strength of the shoulder internal rotator muscles in collegiate level athletes in terms of both peak torque and total work, at either speed that was tested.
- The double mouthguard significantly improved isokinetic muscle strength of the knee extensor muscles in collegiate level athletes in terms of peak torque at a speed of 60 degrees per second, but had no impact on any other variable at this speed. Additionally, the double mouthguard significantly improved isokinetic muscle strength of the knee extensor muscles in collegiate level athletes in terms of total work at 180 degrees per second, but had no significant effects on any other variable at this speed.
- The double mouthguard did not significantly improve isokinetic muscle strength of the shoulder external rotator muscles in collegiate level athletes in terms of both peak torque and total work, at either speed that was tested.
- The double mouthguard did not significantly improve isokinetic muscle strength of the shoulder internal rotator muscles in collegiate level athletes in terms of both peak torque and total work, at either speed that was tested.
- Neither the upper nor the double mouthguards had a significant impact on improving jump height while performing a vertical squat jump.

Comparisons to the Literature

The fact that this study primarily produced non-significant results establishes a foreground into the realm of research for non-custom mouthguards and their effects on strength. Since no literature has been completed in regards to oral appliances that are not molded to the teeth (i.e. nightguards, non-custom mouthguards, etc.), it is difficult to compare these results with those of past research without bias. However, some contrast to studies with similar platforms is vital towards evaluating of the results. Although these studies used a different appliance type and different mechanisms of acquiring data were used, comparisons are still appropriate for the lack of more comparable research. In the case of this particular study, experiments that used the MORA appliance and those that used wax bite registrations were used.

The results of this study contradict the literature completed in the field of mandibular adjustment and strength changes in athletes. Studies that used athletes not inflicted with TMD found improvements in strength when a MORA was utilized; these improvements conflict with those concluded in this study, in that those such improvements were not consistently seen in this study (Verban, Groppel, Pfautsch, & Ramseyer, 1984). However, research that specifically employed athletes inflicted with TMD found non-significant improvements in strength, particularly with the use of a MORA, suggesting that the methods of attempting to exclude TMD athletes were not suitable (Burkett & Bernstein, 1982), due to lack of control over the internal validity of the experiment. When studies used wax bite registrations, improvements were also found for muscular strength performances (Smith, 1978; Williams, Chaconas, & Bader, 1983).

While executing the study, the researcher found many subjects with “open bites” – a common display in *asymptomatic* TMD patients. These subjects were not excluded from the study. The fact that these subjects were approved for participation may have affected the data. In 2008, Murakami, Maeda, Ghanem, Uchiyama, and Kreiborg tested the influence of mouthguard on the Temporomandibular Joint. For the participants who had TMD (anterior disk displacement), the authors concluded that athletes with an internal derangement of the TMJ not wear “thick” mouthguards, and attention should be made to the placement of the mouthguard; in fact, Murakami and his colleagues found that in this case, such a mouthguard (which was similar in material and type to the mouthguards used in this study) should only be placed after examining the patient including completing a Magnetic Resonance Image (MRI) on the joint in order to place the mouthguard properly in its proper “setting” in the mouth. Simply helping the athlete put the mouthguard in his or her mouth properly with no other considerations may have been a factor in this study’s results.

Reasons for Results

In looking at the data for the knee and jump height tests, there were indeed improvements; however, most of these improvements were not high enough to be determined “significant” (at the 0.05 level). In terms of the shoulder, there seems to have been no detriment or improvement in the isokinetic ability tested. This directs the researcher to believe that there is a potential to see improvements in muscle strength and jump height. The lack of significance may have been due to the following possible reasons.

For one, in that the shoulder seems to have been unaffected by the mouthguards which were tested, while the knee was slightly improved, leads the researcher to suggest a reasoning as to why such results came about. In that the knee is a more stable, weight-bearing joint with 2 degrees of freedom, while the shoulder has much less restriction at 3 degrees of freedom and is not weight-bearing should be considered as a contributing factor. The stability and structure of the knee allows for stronger ligaments and therefore a stronger joint structure; this may contribute to a stronger "pulley" in the kinetic chain in terms of the effect of placing a mouthpiece in the oral cavity and testing its effect on the rest of the body.

Secondly, the data suggests that there was little control over the size and construction of the mouthguard. Although the study intended to test over-the-counter, non-custom, stock mouthguards, which was the same for all subjects who used the same mouthguard type (i.e., all of the upper mouthguards and all of the double mouthguards were the same brand and model), there was little ability to account for differential effects because each person's bite is unique. The mouthguard may have not been the correct size for all subjects. For example, one participant complained that the mouthguard was too big for her mouth, while another participant complained of difficulty breathing while wearing the mouthguard. In order to maintain control over the mouthguard in its non-custom form, modifications to mouthguards – such as cutting off some length from the ends in order to make a smaller size – were not made. One must also consider that a mouthguard that may have been too small would have been impossible to alter in a non-dental laboratory setting, therefore supporting the idea that the mouthguards should not have been altered, despite discomfort experienced by some participants. In order to account for those subjects for whom the mouthguard did not fit properly, it may be necessary to perform several adjustments to the presented methodology. While keeping with the purpose of testing affordable non-custom mouthguards, it would be interesting to see the affects of a mouthguard that is the same in its character of being a stock mouthguard, but is available in more sizes, thicknesses (to account for deeper bites), and positioning.

The make-up of the groups should also be considered in that the sports that the athletes participate in may have been a contributing factor towards the results. The athletes were randomly placed into the four groups, and the following table displays the makeup of these groupings:

Table 3

Teams Represented by Participants in each Group

	Basketball	Soccer	Baseball	Softball	Golf	Rowing	Volleyball	Total
Group 1	1	2		1	1	1		6
Group 2	1	2	3					6
Group 3	1	1	1	1			2	6
Group 4	2	2	1			1		6
Total	5	7	5	2	1	2	2	24

If this experiment was to be repeated, it may be of interest to account for team-type while randomly placing athletes in groups. In addition, utilizing an even number of athletes from each sport, and increasing the group size will allow for a greater ability to infer the results to the entire collegiate athlete population.

Lastly, in observing the impacts of mouthguard use on the variables Peak Torque and Total Work, one can see that torque improved, whereas work was left with little effect. The Peak Torque considered the most powerful output during a set; on the other hand, total work was calculated based on the entire set of exercises for each test type.

Clearly, by having improvements in torque, this leads one to suggest that non-endurance athletes wear mouthguards for the purpose of the potential to improve strength and jump height. However, in that the total work did not decline, endurance athletes should continue to wear protection during their athletic activity, for the purpose of the protection of the teeth and oral mucosa.

Future Research

In terms of future research, modifications can be made to this study in order to reveal more accurate results. For one, modifications in mouthguard should be made for each participant, in which smaller and larger-sized mouthguards of the same model type should be available for use. In addition, there should be stricter exclusions for asymptomatic TMD participants; while executing the study, the author found many subjects with “open bites” – a common display in asymptomatic TMD patients. However, these subjects were not excluded from the study. In order to appropriately exclude subjects that are asymptomatic TMD patients, it may be necessary to employ the use of an oral examination performed by dentist instead of the Subject Profile Questionnaire for the exclusion of unqualified participants. Contrastingly, in the case in which a dentist may not be available to perform an oral examination, it would be interesting to see the effects of therapy (such as ultrasound or massage) on all participants before placing the mouthguard in the mouth. This may help place some control over the fact that some subjects may have an open bite and/or are asymptomatic TMD patients.

In terms of further improvements for this study, testing other joints of the body, including the hip, elbow, and ankle should be considered when examining the effects of bite condition (with or without a mouthguard) on muscular strength. By examining such joints as these, the ability to infer the results to a wider range of athletes may be possible. In addition, another test that should be considered is electromyography (EMG). Possessing such data would enable the researcher to provide the activity within the individual muscles, as opposed to the muscle groups that conduct the specific action on the joints.

In conclusion, it is appropriate to say that according to the results, mouthguard use has little effect on muscular strength for the knee and the shoulder, as well as on jump height. However, it is not known whether there's an effect on additional joints that all play a part in the kinetic chain of the body. Although there is little support in that significant improvements were only seen in the knee joint for Peak Torque Away at 60 degrees per second and Total Work Away at 180 degrees per second, this improvement may make a difference for some athletes, especially those to which knee extension is often performed (i.e., rowing, kicking in soccer, and any sport that involves running). Regardless, it is the researcher's opinion that mouthguards, whether upper or double in type, should still be used as a means of protection for the teeth and mouth during athletic activity, particularly while playing contact sports.

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APPENDICES

APPENDIX A

Informed Consent

Barry University
Informed Consent

Your participation in a research project is requested. The title of the study is Impacts of non-custom mouthguards on muscular strength performance in collegiate-level athletes. The research is being conducted by Magda Reda AbdelFattah, a student in the Sport and Exercise Science department of the School of Human Performance and Leisure Sciences at Barry University, and is seeking information that will be useful in the field of Injury and Sport Biomechanics. The aims of the research are to assess the effects of mouthguard use on muscle strength and vertical jump height. In accordance with these aims, the following procedures will be used: collegiate-level athlete participants will each be asked to perform five different tests, two performed on the knee, two performed on the shoulder, and one jumping test. Each of the tests conducted on the knee and the shoulder is comprised of six sets of 5 repetitions using a dynamometer, which is a machine that measures muscular strength. For the jump test, 6 vertical jumps will be performed. You will be randomly placed into one of four groups. Two of these groups will use an upper mouthguard during the exercises, whereas the other two groups will use a double mouthguard during the exercises. Data will be sent from the dynamometer to a computer, in which the set with the highest muscular strength for each athlete will be recorded, analyzed and evaluated, in addition to the total of the repetitions of each set for each test. Additionally, the average of your two sets of 3 jumps will be collected and analyzed. Both individual and collective results will be examined for the subjects. We anticipate the number of participants to be thirty-two collegiate-level athletes.

If you decide to participate in this research, you will be asked to do the following: at first you will be instructed to stretch as you normally would. The order of the tests will be random for each participant. For the vertical jump test, you will perform three vertical jumps with a mouthguard and three vertical jumps without a mouthguard, each time using both feet to jump off the ground. For the strength tests, you will sit down on the dynamometer chair and you will be fastened into the machine by a Velcro straps placed across the chest and legs, as well as the limb being tested. The twenty-four sets of 5 repetitions of shoulder and knee testing conducted will all be the same except for the use of the mouthguard for half of the sets; in addition, one of each of the knee tests and the shoulder tests will be performed at a faster speed than the other test. You will be given a three-minute rest period between trials. We estimate that it will take 1 hour for your participation in the research study; as such, the five different tests will all be completed in the same day.

Your consent to be a research participant is strictly voluntary and should you decline to participate or should you choose to drop out at any time during the study, there will be no adverse effects on your standing in the Barry community. Furthermore, you may refuse to participate or you may withdraw yourself from participating at any time.

The risks of involvement in this study are low and include physical injuries that may consist of bruising, muscle soreness, or discomfort. The following procedures will be used to minimize these risks: the participants will be advised to follow the instructions carefully, and will indicate to the tester if any discomfort is experienced. It should be noted that the mouthguards used will be brand new for each participant; the package will be opened in front of the participant and no mouthguards will be reused between participants. The risk of a cross-contamination by the mouthguards will therefore be minimized. There are no direct benefits to the participant by taking part in this study. However, the indirect benefits may include the acquiring of information that will assist in your training in knowing the power created by your shoulders and knees as determined by the machine both with and without a mouthguard. With this information, you will be able to make the decision as to whether or not you can incorporate mouthguard use into your strength and conditioning routines. You will also contribute to better our understanding as researchers of the aspects of mouthguard use on muscular strength and functional performance effects.

As a research participant, information you provide will be held in confidence to the extent permitted by law. Pictures may be taken of you during the study; however, if used, a black line will be placed over the eyes in order to conceal your identity. These pictures will only be used for the presentation of the study's results. Participant identification numbers, not names, will be used to identify subjects at all times throughout the study. 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 home. Your signed consent form will be kept separate from the data. All data will be destroyed after five years.

If you have any questions or concerns regarding the study or your participation in the study, you may contact me, Magda AbdelFattah, at (561) 703-1667, my supervisor Dr. Claire Egret, at (305) 899-3490, or the Institutional Review Board point of contact, Barbara Cook, at (305) 899-3020. If you are satisfied with the information provided and are willing 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 Magda AbdelFattah 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 participate in this experiment.

______________________ __________

Signature of Participant *Date*

______________________ __________ ______________________ ______

Researcher *Date* *Witness* *Date*

(Witness signature is required only if research involves pregnant women, children, other vulnerable populations, or if more than minimal risk is present.)

APPENDIX B

Subject Profile Questionnaire

Subject Profile Questionnaire

All information will be kept confidential. Please fill out as accurately as possible.

Name ________________________ Date of Birth________________________

Height________________________ Weight_____________________________

Gender (Please Circle one) Male Female

Are you a student-athlete? Yes ______ No _______

If yes, which varsity team are you a member? *Please indicate*

Basketball _____ Soccer _____ Rowing ______ Baseball _______
Softball ______ Tennis ______ Volleyball ______ Golf ______

For how many years have you participated in this sport?
____

History:

1. Have you ever had a jaw injury? Yes ______ No _______

If yes, please explain when and what type:

2. Has a dentist or physician ever diagnosed you with having Temporomandibular Joint Disorder (also known as TMJ, TMD, or TMI)? Yes ______ No _______

If yes, please explain when and what type:

3. If you currently experience any of the following, please indicate:

Clicking of the jaw ______
Pain when moving the jaw ______
Irregular movement of the jaw ______
Difficulty chewing or speaking ______
Pain in the head (headache) ______
Pain in the ear ______
Pain in the sinus ______
Pain in the throat ______
Hearing problems with no history of deafness _______

If you have indicated any of the selections above, please elaborate on when the experience(s) began and how often it (they) occur(s):

Participant ID Number: ___________

APPENDIX C

Data Collection Forms

Data Collection Form - Knee

Experimenter Use Only

Participant ID Number: ________________ Group Number: _______________

Knee 60/60 con/con				
	Peak Torque Away (PTA)	Total Work Away (TWA)	Peak Torque Towards (PTT)	Total Work Towards (TWT)
Set 1				
Set 2				
Set 3				
Average				
Set 4				
Set 5				
Set 6				
Average				

Knee 180/180 con/con				
	Peak Torque Away (PTA)	Total Work Away (TWA)	Peak Torque Towards (PTT)	Total Work Towards (TWT)
Set 1				
Set 2				
Set 3				
Average				
Set 4				
Set 5				
Set 6				
Average				

** “Away” = Knee Extension; “Towards” = Knee Flexion

Data Collection Form - Shoulder

Experimenter Use Only

Participant ID Number: ________________ Group Number: _______________

Shoulder 60/60 con/con				
	Peak Torque Away (PTA)	Total Work Away (TWA)	Peak Torque Towards (PTT)	Total Work Towards (TWT)
Set 1				
Set 2				
Set 3				
Average				
Set 4				
Set 5				
Set 6				
Average				

Shoulder 180/180 con/con				
	Peak Torque Away (PTA)	Total Work Away (TWA)	Peak Torque Towards (PTT)	Total Work Towards (TWT)
Set 1				
Set 2				
Set 3				
Average				
Set 4				
Set 5				
Set 6				
Average				

** “Away” = Shoulder External Rotation; “Towards” = Shoulder Internal Rotation

Data Collection Form – Vertical Squat Jump

Experimenter Use Only

Participant ID Number: ________________ Group Number: ________________

Mouthguard	Height of jump (cm)	Average (cm)
Jump 1		
Jump 2		
Jump 3		
No mouthguard	Height of jump (cm)	
Jump 1		
Jump 2		
Jump 3		

APPENDIX D

Descriptive Statistics Tables

Table 4

Descriptive Statistics - Isokinetic Knee Flexion/Extension with Con/Con 60/60

Variable	Group	Mean	SD
Peak Torque Away (ft-lbs) – No Mouthguard	1	68.33	20.98
	2	106.60	51.31
	3	81.66	34.34
	4	88.15	30.32
Peak Torque Away (ft-lbs) – Mouthguard	1	84.27	27.01
	2	111.60	55.75
	3	93.24	44.91
	4	83.40	30.51
Total Work Away (J) – No Mouthguard	1	152.77	78.47
	2	258.22	172.33
	3	191.89	138.77
	4	215.60	110.76
Total Work Away (J) – Mouthguard	1	169.88	71.79
	2	252.45	162.85
	3	225.38	189.62
	4	206.00	125.38
Peak Torque Towards (ft-lbs) – No Mouthguard	1	51.73	16.82
	2	70.82	23.81
	3	63.03	13.51
	4	67.65	26.56
Peak Torque Towards (ft-lbs) – Mouthguard	1	65.38	13.59
	2	75.28	22.80
	3	71.10	14.45
	4	64.10	28.10
Total Work Towards (J) – No Mouthguard	1	155.82	91.97
	2	222.33	74.73
	3	181.67	88.25
	4	221.22	125.71
Total Work Towards (J) – Mouthguard	1	200.07	85.42
	2	225.33	87.10
	3	219.62	116.11
	4	224.33	159.95

Table 5

Descriptive Statistics - Isokinetic Knee Flexion/Extension with Con/Con 180/180

Variable	Group	Mean	SD
Peak Torque Away (ft-lbs) – No Mouthguard	1	51.55	12.82
	2	65.38	42.33
	3	28.40	13.49
	4	51.73	18.45
Peak Torque Away (ft-lbs) – Mouthguard	1	69.02	21.01
	2	67.67	38.13
	3	46.55	21.96
	4	48.10	24.99
Total Work Away (J) – No Mouthguard	1	112.89	52.94
	2	170.00	151.23
	3	57.23	45.52
	4	120.70	73.76
Total Work Away (J) – Mouthguard	1	147.72	73.31
	2	157.38	126.84
	3	99.70	80.56
	4	109.72	81.79
Peak Torque Towards (ft-lbs) – No Mouthguard	1	57.95	27.52
	2	40.07	23.87
	3	25.45	5.96
	4	39.05	23.43
Peak Torque Towards (ft-lbs) – Mouthguard	1	75.05	66.24
	2	53.45	22.47
	3	42.78	13.75
	4	39.60	25.55
Total Work Towards (J) – No Mouthguard	1	109.80	70.22
	2	105.18	89.07
	3	49.63	29.18
	4	111.23	94.99
Total Work Towards (J) – Mouthguard	1	121.22	85.12
	2	129.62	61.08
	3	89.10	51.30
	4	111.00	98.98

Table 6

Descriptive Statistics - Isokinetic Shoulder Internal/External Rotation Test with Con/Con 60/60 Modified Neutral

Variable	Group	Mean	SD
Peak Torque Away (ft-lbs) – No Mouthguard	1	9.98	3.95
	2	18.67	8.54
	3	14.48	7.78
	4	10.65	3.71
Peak Torque Away (ft-lbs) – Mouthguard	1	9.88	2.27
	2	18.23	9.15
	3	13.12	4.43
	4	11.22	3.26
Total Work Away (J) – No Mouthguard	1	64.45	33.54
	2	69.88	30.87
	3	68.40	27.54
	4	51.45	17.51
Total Work Away (J) – Mouthguard	1	51.67	21.18
	2	75.00	43.11
	3	66.62	25.04
	4	55.22	30.92
Peak Torque Towards (ft-lbs) – No Mouthguard	1	20.23	5.10
	2	40.60	18.29
	3	29.12	15.17
	4	24.63	5.57
Peak Torque Towards (ft-lbs) – Mouthguard	1	21.43	3.60
	2	42.35	17.34
	3	30.18	13.54
	4	25.12	6.03
Total Work Towards (J) – No Mouthguard	1	131.95	47.25
	2	218.83	61.47
	3	189.07	100.61
	4	173.40	32.91
Total Work Towards (J) – Mouthguard	1	152.33	36.39
	2	233.45	70.79
	3	195.02	72.80
	4	175.15	44.82

Table 7

Descriptive Statistics - Isokinetic Shoulder Internal/External Rotation with Con/Con 180/180 Modified Neutral

Variable	Group	Mean	SD
Peak Torque Away (ft-lbs) – No Mouthguard	1	15.05	4.93
	2	19.03	8.00
	3	14.72	8.57
	4	14.93	3.76
Peak Torque Away (ft-lbs) – Mouthguard	1	14.27	5.04
	2	19.60	8.47
	3	16.47	7.45
	4	16.67	4.21
Total Work Away (J) – No Mouthguard	1	43.22	30.38
	2	51.47	34.90
	3	41.82	40.85
	4	39.78	16.23
Total Work Away (J) – Mouthguard	1	33.47	18.70
	2	54.87	31.55
	3	47.28	36.67
	4	41.47	16.56
Peak Torque Towards (ft-lbs) – No Mouthguard	1	20.85	4.85
	2	34.45	12.36
	3	19.33	13.55
	4	23.07	7.36
Peak Torque Towards (ft-lbs) – Mouthguard	1	23.02	3.82
	2	34.23	8.07
	3	23.87	13.01
	4	22.12	9.60
Total Work Towards (J) – No Mouthguard	1	113.67	42.49
	2	167.83	96.83
	3	94.00	73.34
	4	133.27	78.26
Total Work Towards (J) – Mouthguard	1	133.28	31.69
	2	162.22	67.01
	3	123.78	88.70
	4	125.39	92.74

Table 8

Descriptive Statistics – Jump Height

Variable	Group	Mean	SD
Height Difference (cm) – No Mouthguard	1	40.12	4.68
	2	59.97	11.27
	3	44.80	11.34
	4	46.52	13.94
Height Difference (cm) – Mouthguard	1	42.68	5.82
	2	64.63	15.25
	3	48.29	14.18
	4	47.42	14.75

APPENDIX E

Thesis in Manuscript Form

Impacts of Non-Custom Mouthguards on Muscular Strength and Vertical Jump Height in Collegiate Athletes

Magda Reda AbdelFattah

Barry University

Abstract

The purpose of this study was to examine the impacts of non-custom mouthguards on muscular strength performance of the knee and shoulder joint, as well as jump height in collegiate athletes who do not manifest Temporomandibular Joint Disorder (TMD). Twenty-four college students volunteered to participate, all of who were current members of varsity-level teams. The subjects were divided into four groups; two of these groups used an upper mouthguard, and the other two groups used a double mouthguard; there were also differences in the order in which the mouthguard was used. The data for muscular strength was taken as the participant was seated in a stabilized chair of a Biodex System 3 dynamometer, while the jump height was assessed using a Vertec jump height apparatus. Repetitions of knee flexion/extension and shoulder external rotation/internal rotation at 60 degrees per second and 180 degrees per second were taken, as well as jump height differentials. Measurements were recorded for the single peak torque and total work, as well as jump height for each of the sets and jumps for all groups; the average of the first three sets and the average of the last three sets were used for data analysis.

Seventeen 4 x 2 mixed-model ANOVAs were calculated to examine the effects of group and test (with mouthguard/without mouthguard) on each measured variable. Significant effects were only found for peak torque away at 60 degrees per second and for total work away at 180 degrees per second; all other data was deemed not significant. Results may have been affected by inappropriate fit of mouthguard treatment or the inability to exclude asymptomatic TMD participants. Future research should investigate the effects of mandibular adjustment on the different joints of the body, as well as utilize

varying sizes of mouthguards while still maintaining the non-custom aspect of the appliances.

Impacts of Non-Custom Mouthguards on Muscular Strength and Vertical Jump Height in Collegiate Athletes

It is recognized that the use of mouthguards for protection in sports is an important issue; several athletic organizations have adopted mandatory regulations for the utilization of these oral appliances during play, particularly football organizations such as the National Football League and National Collegiate Athletic Association (Knapik et al., 2007; von Arx, Flury, Tschan, Buergin, & Geiser, 2008). Although many athletes understand the idea that mouthguards should be worn for injury prevention of the mouth and surrounding tissues, relatively few individuals regularly wear a mouthguard during training and competition in the cases in which they are not mandated to wear one, citing reasons such as difficulty with conversation, sense of discomfort, feelings of vomiting, breathing difficulties, and an increased secretion of saliva (Tanimoto et al., 2007). Other reasons for the lack of mouthguard use for contact sport athletes included a worry that mouthguards may interfere with athletic performance (Lieger & von Arx, 2006).

In an attempt to encourage the utilization of mouthguards, a number of studies have investigated the effects of mandibular positioning and their potential abilities to improve athletic performance. Mouthguards are essentially soft, oral appliances; therefore, the occlusion of the teeth is manipulated when a mouthguard is placed into the mouth, as when is any type of oral appliance. Because of this, in addition to protecting the teeth to prevent tooth loss during a high-contact activity, mouthguards can also be used to reposition the mandible and change the articulation of the teeth. A complex relationship exists between the joint of the jaw and the muscles of the head and neck, as well as the entire body. Building upon this association, appliances that reposition the mandible can help reduce stress and tension in the muscles, improve abnormalities in body posture, and increase physiological and exercise performance (McArdle et al., 1984). These changes can be attributed to the fact that a mouthpiece acts as both a stabilizer and a shock absorber (Knapik et al., 2007).

Early research into the study of mandibular adjustment to increase muscular strength included simple wax bite registrations as opposed to an oral appliance that molds to the entire upper and/or lower arches of the teeth. In a study whose efforts was to obtain objective evidence that body muscular strength is correlated to posture and condition of the jaw, Smith created wax bites for the ideal occlusal position for professional football subjects. At first, the author compared positions of the usual bite of the subjects with the new position (using the wax bites) in tests of resistance strength of the forearm. A significant difference of the arm's ability to resist downward movements between the two testing conditions was found. In the same study, Smith (1978) further tested subject's strength using a Cybex II dynamometer, and found that a correlation, although weak, was positive for the use of wax bites to position the jaw in order to increase muscular strength.

Most research in the area of mandibular adjustment and its effects on muscular strength has used the Mandibular Orthopedic Repositioning Appliance (MORA) as the treatment appliance to compare strength changes in participants. Verban, Groppel, Pfautsch, and Ramseyer examined 20 undergraduate students to determine the effects of three different bite conditions – a MORA, a placebo, and no appliance – on shoulder strength (1984). The authors conducted shoulder strength tests using a Cybex II dynamometer and found an increase in shoulder strength in comparing the MORA to the other two bite conditions. Williams, Chaconas, & Bader – also using a Cybex II dynamometer – found similar results when examining 23 male varsity athletes and the effects of MORA on both shoulder strength (abduction and adduction) and knee flexion and extension. Although they did not indicate a stabilization of the trunk (which could lead subjects to use lateral leverage of the trunk during the exercises), they concluded that mandibular position may affect appendage muscular strength (1983).

In terms of research that utilized mouthguards as the oral appliance treatment to assess muscular strength chances, Stenger, Ricketts, Lawton, and Wright worked with a professional football team and examined effects of kinesiologically adjusting players' mouthguards (1982). By posturing the mandible through the use of a wax bite added to the mouthguards, the authors found an increase in muscular strength for a qualitative arm test; a dynamometer was not employed to collect data in this study.

Although there is extensive exploration into examining the use of a wide variety of fitted oral appliances for muscular strength performance, there literature lacks investigation into the effects of non-fitted mouthguards on strength. Therefore, the purpose of this investigation was to carefully examine the impacts of a non-custom mouthguard on knee flexion and extension strength, shoulder external and internal rotation strength, and – adding a functional application – the effects of such mouthguards on vertical jump height. Overall use of mouthguards in collegiate-level sports is lacking, and the possible potential added benefits drove the desire to investigate the effects of mouthguards on muscular strength, an essential athletic factor.

The research presented in this manuscript was specifically concerned with the function the mentioned muscle groups in a controlled setting, using four groups: two groups that received an upper mouthguard treatment, and two groups that received a double mouthguard treatment (“double” meaning a mouthguard that covered both the upper and lower teeth). The difference between the two groups that used the same mouthguards was found in the order in which the mouthguard was used, as mentioned in the methodology of this study. Additionally, each joint was tested at two different speeds, 60 degrees per second and 180 degrees per second. It was hypothesized that mouthguard use, whether it was the upper or double mouthguard, would significantly improve isokinetic muscular strength in terms of torque and work on all occasions, as well as jump height.

Method

Participants

For this investigation, 26 volunteer participants were randomly selected by recruitment through athletic trainers and coaches from the pool of undergraduate collegiate athletes, ages 18 and older, at Barry University (8 males and 18 females), all of who were current members of a varsity level team. After each participant had completed a Subject Profile Questionnaire, subjects were either approved or declared as unqualified to participate. Questions presented on the form included whether the participants had past jaw injuries, if a dentist or physician had diagnosed the participant of Temporomandibular Joint Disorder (TMD), and the current symptoms the participant was experiencing. The reason for excluding subjects who experienced any type of jaw injury or displayed symptoms of TMD was due to efforts to place control on the experiment. Any mandibular adjustment in these participants would likely cause an improvement in overall function, which could distract from the effects the mouthguard has on the athlete. Of the 26 volunteers, 24 were approved for participation, and were members of the softball, baseball, basketball, rowing, golf, volleyball, and soccer teams.

Instruments

A Biodex System 3 dynamometer positioned in the Athletic Training Lab inside the Health and Sports Center of Barry University was used to measure the strength of the tested muscles acting on the knee and shoulder. The Biodex System 3 is considered to measure strength with acceptable mechanical reliability and validity at all speeds except those that are 300 degrees per second or higher for all variable types (Drouin, Valovich-McLeod, Shultz, Gansneder, & Perrin, 2004). This study used a speed of 60 degrees per second. In terms of measuring jump height, the Vertec Jump Height Test apparatus located in the Biomechanics Lab inside the Health and Sports Center of Barry University was used; the Vertec has been shown to be a valid and reliable apparatus when used in the following manner: first, the standing height of the subject with one arm fully extended upward was taken. Then, the subject jumped up and touched the highest possible vane. The difference between standing height and jumping height was then measured (Hutchinson & Stone, 2009).

Procedures

The subjects were divided into four groups based on the order in which they signed up for the study. Therefore, the first participant was placed into group 1, the second participant was placed into group 2, the third participant was placed into group 3, and the fourth participant was put into group 4; participant 5 began this placement cycle over, meaning he or she was placed into group 1, and so forth. The difference between the groups was found in both the mouthguard type and in the order of isokinetic testing (see Table 1). For each participant, vertical jump height was assessed after performing isokinetic testing of both the knee and shoulder, at the two different speeds; however, the order in which the joints and the speeds at which those joints were tested was random. Subjects were only known as their assigned participant identification numbers throughout the entire study.

First, the subject was placed into the dynamometer chair. Setup of the Biodex apparatus followed instructions given by the Biodex System 3 software; these were different for the knee and shoulder tests. Diagonal straps were placed across the trunk, one over each shoulder, as well as across the upper thigh of the left legs. Additionally, during the knee tests, there was an additional strap across the mid-calf of the right leg, while for the shoulder tests, there was a specific rotating attachment that allowed for stabilization of the right elbow and forearm for proper shoulder movement. These straps helped to ensure that the motion was restricted to the tested limb and that no assistance could be done by such leveraging actions of the other parts of the body. The chair of the dynamometer was adjusted to each of the participant’s dimensions, including chair elevation, depression; backwards movement and forwards movement, so that each participant could properly execute the exercises.

The protocols used by the Biodex System 3 were the Isokinetic Knee Flexion/Extension test with Con/Con 60/60, Isokinetic Knee Flexion/Extension test with Con/Con 180/180, Isokinetic Shoulder External/Internal Rotation Modified Neutral test with Con/Con 60/60, and Isokinetic Shoulder External/Internal Rotation Modified Neutral test with Con/Con 180/180. This protocol indicated that the joint would be concentrically flexing as well as concentrically flexing at either 60 degrees per second or 180 degrees per second. Range of motion was taken for each participant, by having his or her full extension (external rotation) and full flexion (internal rotation) recorded while in the chair by the dynamometer before the sets began. Each protocol was assessed in six sets of five repetitions each, as seen in Table 1. All of the subjects performed the movements while strapped into the dynamometer and holding onto handlebars attached at the sides of the chair. Each repetition had the subjects move through the full available range of motion of the joint while in the chair, and participants performed the exercises to the best of their abilities.

Table 1
Order of Isokinetic Testing Organized by Group

Group 1 (No Mouthguard/ Upper Mouthguard)	Group 2 (Upper Mouthguard/ No Mouthguard)	Group 3 (No Mouthguard/ Double Mouthguard)	Group 4 (Double Mouthguard/ No Mouthguard)
Set 1: No mouthguard	Set 1: Upper mouthguard	Set 1: No mouthguard	Set 1: Double mouthguard
1 minute rest	1 minute rest	1 minute rest	1 minute rest
Set 2: No mouthguard	Set 2: Upper mouthguard	Set 2: No mouthguard	Set 2: Double mouthguard
1 minute rest	1 minute rest	1 minute rest	1 minute rest
Set 3: No mouthguard	Set 3: Upper mouthguard	Set 3: No mouthguard	Set 3: Double mouthguard
1 minute rest	1 minute rest	1 minute rest	1 minute rest
Set 4: Upper mouthguard	Set 4: No mouthguard	Set 4: Double mouthguard	Set 4: No mouthguard
1 minute rest	1 minute rest	1 minute rest	1 minute rest
Set 5: Upper mouthguard	Set 5: No mouthguard	Set 5: Double mouthguard	Set 5: No mouthguard
1 minute rest	1 minute rest	1 minute rest	1 minute rest
Set 6: Upper mouthguard	Set 6: No mouthguard	Set 6: Double mouthguard	Set 6: No mouthguard

For the vertical jump test, the subject first had his or her standing height with one arm fully extended upward taken. The subject then, from a squatting position, jumped off the ground with two feet and touched the highest possible vane. The difference between standing height and jumping height was then measured. This was repeated six times total, with the first three trials and last three trials differing in mouthguard use according to group assignment. All data was recorded on data sheets that only referred to subjects as the assigned participant identification numbers and the group to which they belonged.

Peak torque and total work values for each of the sets were obtained for both the "away" and "towards" movements, which are the extension or external rotation and flexion or internal rotation actions for the joints, respectively. Peak torque was recorded in foot-pounds, while total work was recorded in Joules. The average of the peak torques and total works from sets one, two and three were compared to the average of the peak torques from each of sets four, five and six (peak torque is the data presented by the Biodex, individual peak torques are not provided for each repetition within a set). For the vertical jump trials, the average of the three trials with the mouthguard and the average of the three trials without the mouthguard was compared for each subject, and furthermore within and between groups. This measurement was made in centimeters. Therefore, comparisons both within groups and between groups will create the results that will be analyzed.

Design Analysis

The data from each participant was entered into PASW Statistic 18.0 Software. In order to compare the isokinetic test results, the average of the sets using the mouthguard (either sets the first three sets or the last three sets) was compared to the other three sets that did not use the mouthguard (either the first three or last three sets). Using the software, the data was first screened and transformed, to ensure accuracy of the data. The following variables were compared: Peak Torque Away, Total Work Away, Peak Torque Towards, and Total Work Towards.

Therefore, 4 x 2 between-within mixed-design ANOVAs were completed for each dependent variable at each speed, for each joint. An additional 4 x 2 between-within mixed-design ANOVA was also done for jump height analysis. There were 17 total mixed-design ANOVAs conducted. This allowed for the comparison of the changes between bite condition (mouthguard or no mouthguard) for each group, as well as a comparison amongst the four different groups.

Results

Tables 2, 3, and 4 reveal the descriptive statistics in regards to the Isokinetic Knee Flexion/Extension test with Con/Con 60/60, Isokinetic Knee Flexion/Extension test with Con/Con 180/180, Isokinetic Shoulder External/Internal Rotation Modified Neutral test with Con/Con 60/60, and Isokinetic Shoulder External/Internal Rotation Modified Neutral test with Con/Con 180/180 protocols, respectively. The graphs shown are those of the results that were found to be significant (peak torque away for the knee at 60 degrees per second, and total work for the knee at 180 degrees per second).

Table 2
Descriptive Statistics – Jump Height

Variable	Group	Mean	SD
Height Difference (cm) – No Mouthguard	1	40.12	4.68
	2	59.97	11.27
	3	44.80	11.34
	4	46.52	13.94
Height Difference (cm) – Mouthguard	1	42.68	5.82
	2	64.63	15.25
	3	48.29	14.18
	4	47.42	14.75

Table 3
Descriptive Statistics - Isokinetic Knee Flexion/Extension

		60/60		180/180	
Variable	Group	Mean	SD	Mean	SD
Peak Torque Away (ft-lbs) – No Mouthguard	1	68.33	20.98	51.55	12.82
	2	106.60	51.31	65.38	42.33
	3	81.66	34.34	28.40	13.49
	4	88.15	30.32	51.73	18.45
Peak Torque Away (ft-lbs) – Mouthguard	1	84.27	27.01	69.02	21.01
	2	111.60	55.75	67.67	38.13
	3	93.24	44.91	46.55	21.96
	4	83.40	30.51	48.10	24.99
Total Work Away (J) – No Mouthguard	1	152.77	78.47	112.89	52.94
	2	258.22	172.33	170.00	151.23
	3	191.89	138.77	57.23	45.52
	4	215.60	110.76	120.70	73.76
Total Work Away (J) – Mouthguard	1	169.88	71.79	147.72	73.31
	2	252.45	162.85	157.38	126.84
	3	225.38	189.62	99.70	80.56
	4	206.00	125.38	109.72	81.79
Peak Torque Towards (ft-lbs) – No Mouthguard	1	51.73	16.82	57.95	27.52
	2	70.82	23.81	40.07	23.87
	3	63.03	13.51	25.45	5.96
	4	67.65	26.56	39.05	23.43
Peak Torque Towards (ft-lbs) – Mouthguard	1	65.38	13.59	75.05	66.24
	2	75.28	22.80	53.45	22.47
	3	71.10	14.45	42.78	13.75
	4	64.10	28.10	39.60	25.55
Total Work Towards (J) – No Mouthguard	1	155.82	91.97	109.80	70.22
	2	222.33	74.73	105.18	89.07
	3	181.67	88.25	49.63	29.18
	4	221.22	125.71	111.23	94.99
Total Work Towards (J) – Mouthguard	1	200.07	85.42	121.22	85.12
	2	225.33	87.10	129.62	61.08
	3	219.62	116.11	89.10	51.30
	4	224.33	159.95	111.00	98.98

Peak Torque Away (Extension): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group (groups 1, 2, 3, and 4) and bite condition (no mouthguard and mouthguard) on peak torque away at 60 degrees per second for the knee. A significant relationship was found between group and bite condition for the peak torque values (*F*(3,20) = 3.239, p < .05). In addition, the main effect for bite condition was also significant (*F*(1,20) = 7.716, p < .05). The main effect for group was not significant

(*F*(3,20) = 0.781, p > .05). Upon examination of the data, it appears that Groups 1, 2, and 3 showed significant improvements when using the mouthguard. (Figure 1)

Table 4
Descriptive Statistics - Isokinetic Shoulder External/Internal Rotation

		60/60		180/180	
Variable	Group	Mean	SD	Mean	SD
Peak Torque Away (ft-lbs) – No Mouthguard	1	9.98	3.95	15.05	4.93
	2	18.67	8.54	19.03	8.00
	3	14.48	7.78	14.72	8.57
	4	10.65	3.71	14.93	3.76
Peak Torque Away (ft-lbs) – Mouthguard	1	9.88	2.27	14.27	5.04
	2	18.23	9.15	19.60	8.47
	3	13.12	4.43	16.47	7.45
	4	11.22	3.26	16.67	4.21
Total Work Away (J) – No Mouthguard	1	64.45	33.54	43.22	30.38
	2	69.88	30.87	51.47	34.90
	3	68.40	27.54	41.82	40.85
	4	51.45	17.51	39.78	16.23
Total Work Away (J) – Mouthguard	1	51.67	21.18	33.47	18.70
	2	75.00	43.11	54.87	31.55
	3	66.62	25.04	47.28	36.67
	4	55.22	30.92	41.47	16.56
Peak Torque Towards (ft-lbs) – No Mouthguard	1	20.23	5.10	20.85	4.85
	2	40.60	18.29	34.45	12.36
	3	29.12	15.17	19.33	13.55
	4	24.63	5.57	23.07	7.36
Peak Torque Towards (ft-lbs) – Mouthguard	1	21.43	3.60	23.02	3.82
	2	42.35	17.34	34.23	8.07
	3	30.18	13.54	23.87	13.01
	4	25.12	6.03	22.12	9.60
Total Work Towards (J) – No Mouthguard	1	131.95	47.25	113.67	42.49
	2	218.83	61.47	167.83	96.83
	3	189.07	100.61	94.00	73.34
	4	173.40	32.91	133.27	78.26
Total Work Towards (J) – Mouthguard	1	152.33	36.39	133.28	31.69
	2	233.45	70.79	162.22	67.01
	3	195.02	72.80	123.78	88.70
	4	175.15	44.82	125.39	92.74

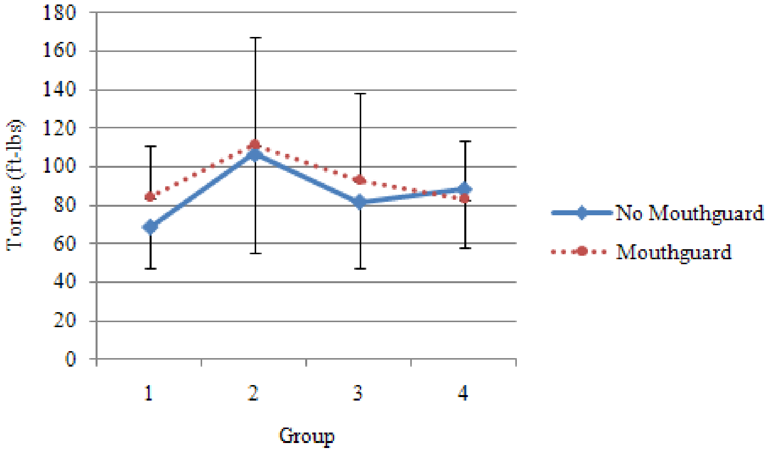

Figure 1. Peak Torque Away of the Knee at 60 deg/sec

Total Work Away (Extension): A 4 x 2 mixed-design ANOVA was calculated to examine the effects of group and bite condition on total work away at 180 degrees per second for the knee. The relationship that was found between group and bite condition was significant (*F*(3,20) = 3.375, p < .05). However, the main effect for bite condition was not significant (*F*(1,20) = 2.834, p > .05). The main effect for group was also not significant (*F*(3,20) = 0.926, p > .05). Upon examination of the data, it appears that Groups 1 and 2 had significant improvements with mouthguard use. (Figure 2)

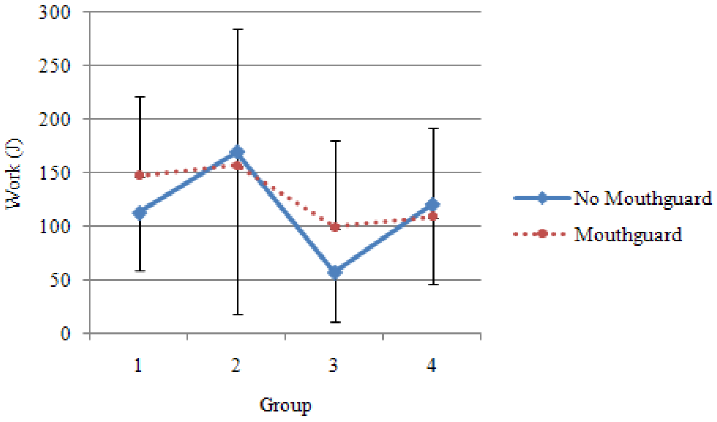

Figure 2. Total Work Away of the Knee at 180 deg/sec

On all other occasions, including the isokinetic muscular strengths and jump heights, the difference between the data recorded while using a mouthguard and not using a mouthguard was deemed not significant. Overall, mouthguard use only significantly improved the strength of the knee in the “away” movement (extension). No impact, in terms of an improvement or a detriment was made on the shoulder joint. Jump height overall was improved, but not enough to be considered significant.

Discussion

The purpose of this study was to determine the impacts of non-custom mouthguards on muscular strength performance on the muscles that act on the knee joint during flexion and extension and the muscles that act on the shoulder joint during external and internal rotation. In addition, the idea of observing the effects of non-custom mouthguards towards a functional application – jump height – was also examined in this study. It was hypothesized that mouthguard use would significantly improve isokinetic muscular strength of each of the muscle group sets (knee flexors, knee extensors, shoulder external rotators, and shoulder internal rotators) both in terms of peak torque and total work. Additionally, it was hypothesized that utilizing mouthguards would significantly improve jump height when performing a vertical squat jump.

Employing the use of the data collected and statistics produced by this study, the following conclusions may be made in our comparisons of the groups: Upper mouthguard: the upper mouthguard significantly improved isokinetic muscle strength of the knee extensor muscles in collegiate level athletes in terms of peak torque at a speed of 60 degrees per second, but had no impact on any other variable at this speed.

Additionally, the upper mouthguard significantly improved isokinetic muscle strength of the knee extensor muscles in collegiate level athletes in terms of total work at 180 degrees per second, but had no significant effects on any other variable at this speed. Also, the upper mouthguard did not significantly improve isokinetic muscle strength of the shoulder external rotator muscles in collegiate level athletes in terms of both peak torque and total work, at either speed that was tested. The upper mouthguard also did not significantly improve isokinetic muscle strength of the shoulder internal rotator muscles in collegiate level athletes in terms of both peak torque and total work, at either speed that was tested. Double mouthguard: the double mouthguard significantly improved isokinetic muscle strength of the knee extensor muscles in collegiate level athletes in terms of peak torque at a speed of 60 degrees per second, but had no impact on any other variable at this speed. Additionally, the double mouthguard significantly improved isokinetic muscle strength of the knee extensor muscles in collegiate level athletes in terms of total work at 180 degrees per second, but had no significant effects on any other variable at this speed. The double mouthguard did not significantly improve isokinetic muscle strength of the shoulder external rotator muscles in collegiate level athletes in terms of both peak torque and total work, at either speed that was tested. The double mouthguard did not significantly improve isokinetic muscle strength of the shoulder internal rotator muscles in collegiate level athletes in terms of both peak torque and total work, at either speed that was tested. Neither the upper nor the double mouthguards had a significant impact on improving jump height while performing a vertical squat jump.

The fact that this study primarily produced non-significant results establishes a foreground into the realm of research for non-custom mouthguards and their effects on strength. Since no literature has been completed in regards to oral appliances that are not molded to the teeth (i.e. nightguards, non-custom mouthguards, etc.), it is difficult to compare these results with those of past research without bias. However, some contrast to studies with similar platforms is vital towards evaluating of the results. Although these studies used a different appliance type and different mechanisms of acquiring data were used, comparisons are still appropriate for the lack of more comparable research. In the case of this particular study, experiments that used the MORA appliance and those that used wax bite registrations were used.

The results of this study contradict the literature completed in the field of mandibular adjustment and strength changes in athletes. Studies that used athletes not inflicted with TMD found improvements in strength when a MORA was utilized; these results conflict with those concluded in this study (Verban, Groppel, Pfautsch, & Ramseyer, 1984). However, research that specifically employed athletes inflicted with TMD found non-significant improvements in strength, particularly with the use of a MORA; this result suggests that the methods of attempting to exclude TMD athletes were not suitable (Burkett & Bernstein, 1982). When studies used wax bite registrations, improvements were also found for muscular strength performances (Smith, 1978; Williams, Chaconas, & Bader, 1983).

While executing the study, the researcher found many subjects with “open bites” – a common display in *asymptomatic* TMD patients. These subjects were not excluded from the study. The fact that these subjects were approved for participation may have affected the data. In 2008, Murakami, Maeda, Ghanem, Uchiyama, and Kreiborg tested the influence of mouthguard on the Temporomandibular Joint. For the participants who had TMD (anterior disk displacement), the authors concluded that athletes with an internal derangement of the TMJ not wear “thick” mouthguards, and attention should be made to the placement of the mouthguard; in fact, Murakami and his colleagues found that in this case, such a mouthguard (which was similar in material and type to the mouthguards used in this study) should only be placed after examining the patient including completing a Magnetic Resonance Image (MRI) on the joint in order to place the mouthguard properly in its proper “setting” in the mouth. Simply helping the athlete put the mouthguard in his or her mouth properly with no other considerations may have been a factor in this study’s results.

In looking at the data for the knee and jump height tests, there were indeed improvements; however, most of these improvements were not high enough to be determined “significant” (at the 0.05 level). In terms of the shoulder, there seems to have been no detriment or improvement in the isokinetic ability tested. This directs the researcher to believe that there is a potential to see improvements in muscle strength and jump height. The lack of significance may have been due to the following possible reasons. For one, in that the shoulder seems to have been unaffected by the mouthguards which were tested, while the knee was slightly improved, leads the researcher to suggest a reasoning as to why such results came about. In that the knee is a more stable, weight-bearing joint with 2 degrees of freedom, while the shoulder has much less restriction at 3 degrees of freedom and is not weight-bearing should be considered as a contributing factor. The stability and structure of the knee allows for stronger ligaments and therefore a stronger joint structure; this may contribute to a stronger “pulley” in the kinetic chain in terms of the effect of placing a mouthpiece in the oral cavity and testing its effect on the rest of the body.

Secondly, the data suggests that there was little control over the size and construction of the mouthguard. Although the study intended to test over-the-counter, non-custom, stock mouthguards, which was the same for all subjects who used the same mouthguard type (i.e., all of the upper mouthguards and all of the double mouthguards were the same brand and model), there was little ability to account for the effects by the fact that each person's bite it unique. The mouthguard may have not been the correct size for all subjects. For example, one participant complained that the mouthguard was too big for her mouth, while another participant complained of difficulty breathing while wearing the mouthguard. In order to maintain control over the mouthguard in it's non-custom form, modifications to mouthguards – such as cutting off some length from the ends in order to make a smaller size – were not made. One must also consider that a mouthguard that may have been too small would have been impossible to alter in a non-dental laboratory setting, therefore supporting the idea that the mouthguards should not have been altered, despite discomfort experienced by some participants. In order to account for those subjects whom the mouthguard did not fit properly, it may be necessary to perform several adjustments to the presented methodology. While keeping with the purpose of testing affordable non-custom mouthguards, it would be interesting to see the affects of a mouthguard that is the same in its character of being a stock mouthguard, but is available in more sizes, thicknesses (to account for deeper bites), and positioning.

The make-up of the groups should also be considered in that the sports that the athletes participate in may have been a contributing factor towards the results. The athletes were randomly placed into the four groups, and the following table displays the make up of these groupings:

Table 5
Teams Represented by Participants in each Group

	Basketball	Soccer	Baseball	Softball	Golf	Rowing	Volleyball	Total
Group 1	1	2		1	1	1		6
Group 2	1	2	3					6
Group 3	1	1	1	1			2	6
Group 4	2	2	1			1		6
Total	5	7	5	2	1	2	2	24

If this experiment was to be repeated, it may be of interest to account for team-type while randomly placing athletes in groups. In addition, utilizing an even number of athletes from each sport, and increasing the group size will allow for a greater ability to infer the results to the entire collegiate athlete population.

Lastly, in observing the impacts of mouthguard use on the variables Peak Torque and Total Work, one can see that torque improved, whereas work was left with little effect. The Peak Torque considered the most powerful output during a set; on the other hand, total work was calculated based on the entire set of exercises for each test type. Clearly, by having improvements in torque, this leads one to believe that suggestions should be made for non-endurance athletes to wear mouthguards for the purpose of the potential to improve strength and jump height. However, in that the total work may be associated with the ability to endure the span of the exercises, and considering that bite condition had little affect on this variable, it is not suggested that endurance athletes not wear protection during their athletic activity; for the purpose of the protection of the teeth and oral mucosa, mouthguards should be worn during all athletic activity, regardless of the type.

In terms of future possible research, modifications can be made to this study in order to reveal more accurate results. For one, modifications in mouthguard should be made for each participant, in which smaller and larger-sized mouthguards of the same model type should be available for use. In addition, there should be more strict exclusions for asymptomatic TMD participants; while executing the study, the author found many subjects with “open bites” – a common display in asymptomatic TMD patients. However, these subjects were not excluded from the study. In order to appropriately exclude subjects that are asymptomatic TMD patients, it may be necessary to employ the use of an oral examination performed by dentist instead of the Subject Profile Questionnaire for the exclusion of unqualified participants. Contrastingly, in the case in which a dentist may not be available to perform an oral examination, it would be interesting to see the effects of therapy (such as ultrasound or massage) on all participants before placing the mouthguard in the mouth. This may help place some control over the fact that some subjects may have an open bite and/or are asymptomatic TMD patients.

In terms of further improvements for this study, testing other joints of the body, including the hip, elbow, and ankle should be considered when examining the effects of bite condition (with or without a mouthguard) on muscular strength. By examining such joints as these, the ability to infer the results to a wider range of athletes may be possible. In addition, another test that should be considered is electromyography (EMG). Possessing such data would enable the researcher to provide the activity within the individual muscles, as opposed to the muscle groups that conduct the specific action on the joints.

In conclusion, it is appropriate to say that according to the results, mouthguard use has little effect on muscular strength for the knee and the shoulder, as well as on jump height. However, it is not known whether there’s an effect on additional joints that all play a part in the kinetic chain of the body. Although there is little support in that significant improvements were only seen in the knee joint for Peak Torque Away at 60 degrees per second and Total Work Away at 180 degrees per second, this improvement may make a difference for some athletes, especially those to which knee extension is often performed (i.e., rowing, and any sport that involves running). Regardless, it is the researcher’s opinion that mouthguards, whether upper or double in type, should still be used as a means of protection for the teeth and mouth during athletic activity, particularly while playing contact sports.

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