Research with Novel Technology: Advances in Concussion Diagnosis and Mouthpiece Utilization during Performance

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Mouthguards are traditionally utilized to protect dentition during contact sports, with specific regulations of its use in various contact sports such as football, field hockey, and lacrosse (ADA Council on Access, 2006; Glendor, 2009; Heintz, 1968; Hughston, 1980; National Federation of State High Schools & Sports Medicine Advisory Committee, 2014; Ranalli & Demas, 2002). However, due to athletes reporting that use of mouthguard inhibit performance, i.e. breathing obstruction, the rates of utilization range from 16-46% (Boffano et al., 2012; Hawn, Visser, & Sexton, 2002; Knapik et al., 2007). Controversial data in the 1970s and 1980s by those associated with sports dentistry suggested that use of a mouthguard could improve performance, with new oral appliance technology called MORA (mandibular orthopedic repositioning appliance) being studied (Fonder, 1976; Kaufman, 1980; Moore, 1981; Boffano et al., 2012; Hawn et al., 2002; Knapik et al., 2007). However, the appropriate focus on methodology associated with physiological data collection during exercise was not well utilized, and subjective aspects of data collection were reported. Thus, the debate around that research persisted in many areas of sports dentistry (Jakush, 1982; Smith, 1978; Smith, 1982; Stenger, 1977; Boffano et al., 2012; Hawn et al., 2002; Knapik et al., 2007; Yates, Koen, Semenick, & Kuftinec, 1984). In early 2000s, new mouthguard technology emerged which claimed to enhance performance, and our laboratory was tasked to discover if physiological aspects of performance improvements could be found. Thus, from 2004 until present, due to the subject population available for our research (trained, healthy 18-21 years old), we have had success in understanding which physiological parameters may be manipulated by mouthguard use and to what extent these parameters change based on the type of mouthguard used.

In order to understand how to research this problem, much investigation has been given to the different types of mouthguards/oral appliances utilized by athletes. Both upper and now lower mouthguards/ oral appliances demonstrate improvements in performance. While our laboratory did initial investigation with a minimalist upper oral appliance, we have primarily focused on a lower oral appliance. The lower appliance and various iterations of the design have been studied in both aerobic and anaerobic protocols to determine if there are changes in physiological aspects to include computed tomography (CT) scans, blood or saliva cortisol, blood lactate levels, and/or respiratory parameters. In each of these areas, we found differences in these parameters with an oral appliance as compared to without an oral appliance (Dudgeon, Buchanan, Strickland, Scheett, & Garner, 2017; Garner & McDivitt, 2009c; Garner & McDivitt, 2009a; Garner & Miskimin, 2009; Garner, Dudgeon, & McDivitt, 2011; Garner & McDivitt, 2015). The question now was why these differences occurred.

The significant reductions in lactate levels lead to evaluating computed tomography (CT) scans of the upper oral appliance to determine if the bite wedges in the oral appliance opened the user's mouth in a specific way (Garner & McDivitt, 2009b; Garner & McDivitt, 2009a; Garner & McDivitt, 2015). In that study, we found that there were improvements in airway openings, specifically the oropharynx area of the throat (Garner & McDivitt, 2009a) (see figure 1). Based on those CT scan findings and research findings in sleep apnea and airway openings, our laboratory then sought to correlate changes in respiratory measures (Fregosi & Ludlow, 2014; Gale et al., 2000; Gao et al., 2004; Hiyama, Iwamoto, Ono, Ishiwata, & Kurodo, 2000; Johal, Gill, Ferman, & McLaughlin, 2007; Kyung, Park, & Pae, 2005; Mann, Burnett, Cornell, & Ludlow, 2002; Miller, 2002; Remmers, 2010; Saboisky et al., 2006; Saito & Itoh, 2003). Using healthy individuals in an upright exercising condition, we assessed changes in respiratory parameters with and without various oral appliances, appliances that changed mandibular and genioglossal/tongue placement. Both respiratory rate and ventilation were consistently lowered in the lower mouthpiece condition (Garner & McDivitt, 2009a; Garner, Dudgeon, Scheett, & McDivitt, 2011; Garner, 2015; Garner & Lamira, 2019). We theorized that these outcomes were caused by to the design of the mouthpiece based on our studies as well as findings in prior studies (Francis & Brasher, 1991; Garner & McDivitt, 2009a; Garner, 2015; Bailey et al., 2015; Bourdin et al., 2006). Specifically, we noted that oral appliances which elicited a greater impact on the tongue internally with a resultant shifting forward of the mandible, affected respiratory parameters more robustly. Literature confirms that the manipulation of the mandible (shift to a more forward position) and subsequent protrusion of the genioglossus (tongue muscle) results in a mechanical opening of areas within the throat region (Gale et al., 2000; Gao et al., 2004; Johal et al., 2007; Kyung et al., 2005).

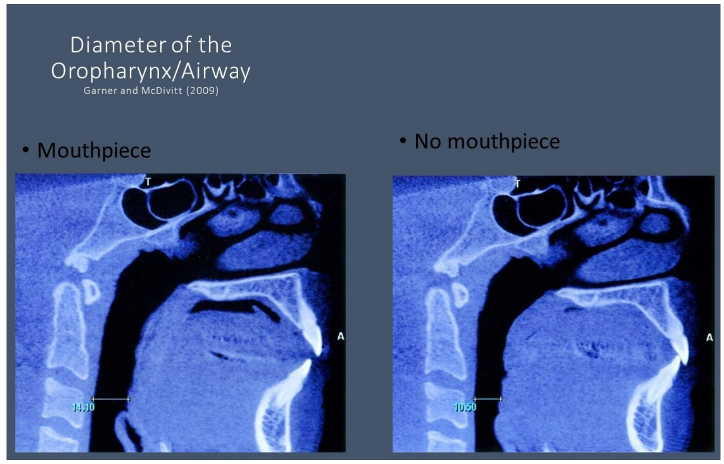

Figure 1.

In addition to understanding the effect of oral appliance use on respiration, our laboratory has studied the impact of clenching during exercise to be beneficial to both salivary and blood cortisol levels. Our research has cited a 39-51% reduction in cortisol post intensive resistance exercise with mouthpiece use as compared to no mouthpiece use (Dudgeon et al., 2017; Garner et al., 2011) (see figure 2). Why this is occurring has yet to be confirmed, but may center on the increase in cerebral blood flow occurring during the clenching process (Hori, Yuyama, & Tamura, 2004; Iida et al., 2010; Iida et al., 2012; Miyake et al., 2008; Momose et al., 1997; Sasaguri et al., 2005; Tamura, Kanayama, Yoshida, & Kawasaki, 2002). For example, when restrained (stressed) rats were given a wooden stick on which to bite, there was an improvement in the stress response as compared to a no wooden stick condition (Hori et al., 2004; Sasaguri et al., 2005). Human studies find that there are significant changes in cerebral blood flow during the activity of clenching as compared to other tasks such as tooth tapping and gum chewing (Hasegawa, Ono, Hori, & Nokubi., 2007; Iida et al., 2010). Interestingly, continuous teeth contact and intensity of the clenching activates areas of the cerebral cortex, which interacts with the hypothalamic-pituitary-adrenal (HPA) axis (Iida et al., 2010; Shibusawa, Takeda, Nakajima, Ishigami, & Sakatani, 2009). Thus, the reductions in cortisol with mouthpiece use, triggered during the stress/exercise response, should be tested to better understand any correlations among clenching and cerebral blood flow.

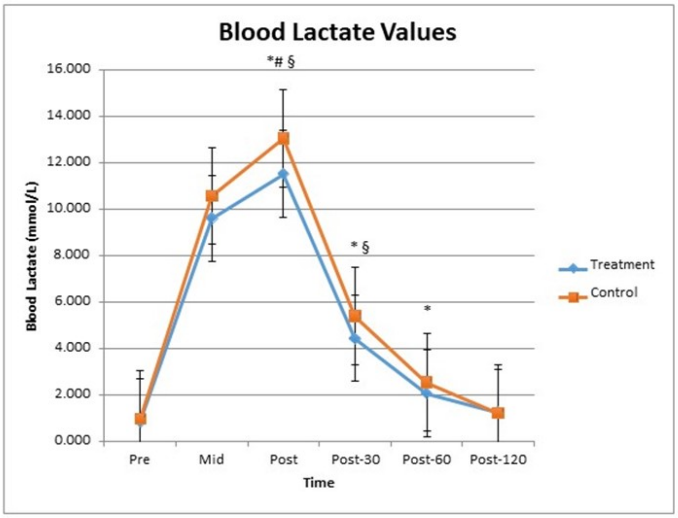

Figure 2.

While our laboratory has contributed substantially to the body of literature relating to mouthguard/oral appliance use and physiological parameters associated with performance, another research area associated with our laboratory has been the collaborative efforts with the Medical University of South Carolina, Zucker Institute for Applied Neurosciences. In 2015, The Citadel was approached to support the refinement, development and testing of a novel eye-tracking device developed by Dr. Nancey Tsai, a MUSC neurosurgeon. In this collaboration, we supported the refinement of the technology to assess blink reflexes as an objective assessment of concussion (Tsai et al., 2017). The Eyestat, now owned by blinkTBI, provides a stimulus to provoke a blink reflex. The blink reflex is then recorded and calculated via algorithms to measure blink parameters such as response time of the primary eye stimulated (latency), the speed of response, and how many blinks occur (oscillations) during a given period. Our first study cited a decrease time in blink latency with concussion as compared to baseline, while oscillations increased with concussion. During active play as compared to baseline, latency increased, while oscillations decreased (Garner et al., 2018) (see figure 3). The cause of these changes needs further evaluation, but initial data suggests this technology provides objective data to support the concussion diagnosis.

These two technologies and their emergent research are examples of how a primarily undergraduate institution (PUI) has integrated students in the research process while collaborating with larger institutions to support outcomes in the state of South Carolina. In both the mouthpiece research and concussion research, students have been given opportunities to learn, present, and collect data, with the goal to facilitate soft skills (critical thinking, oral and written skills) and mentoring between faculty and students (Branch, Cain, Jackson, Tryer, & Garner, 2015; Garner & Lamira, 2019; Lamira & Garner, 2018; Brantley & Garner, 2016; Churchill, Ganer, & Spradlin, 2019). (Interestingly, as I sit in my office writing this article, a group of 5 students from a research class comes to my office to ask if they can work with me on a research project involving the mouthpiece this semester. I am instantly excited to support this group as I know that the hands-on undergraduate research experience is where the learning occurs). While PUIs do not consistently produce a high level of research activity on par with R1 institutions, PUIs can provide unique aspects of mentoring, collaboration, and growth of soft skills needed for this current generation of students. Thus, continued collaborations between industry, R1 schools and PUIs should be further explored for opportunities to engage faculty and students in meaningful ways, thereby supporting growth and development within the state of South Carolina.

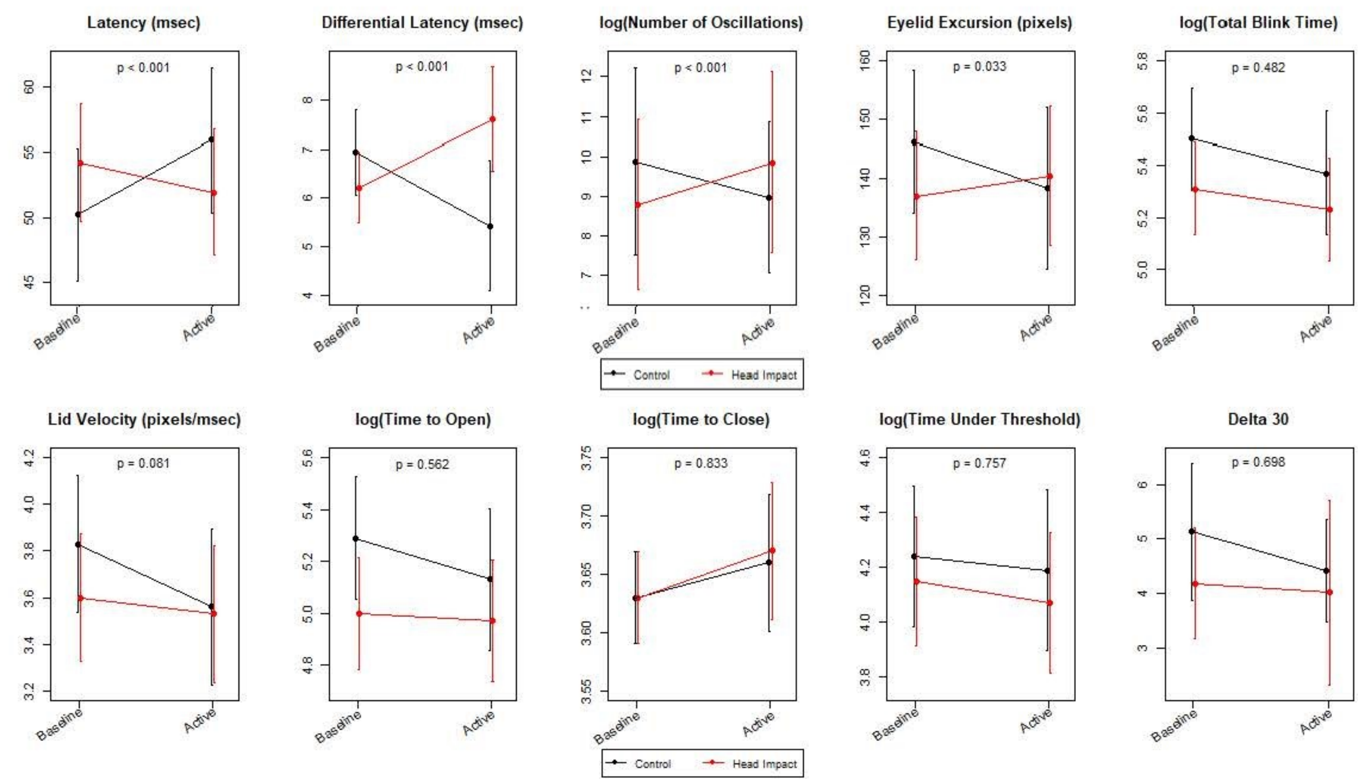

Figure 3. Blink reflex parameter changes from baseline due to active play or head impact. A positive slope indicates that the second measurement was increased on average relative to the baseline measurement. A negative slope indicates that the second measurement decreased relative to the baseline measurement. Black lines represent the mean values for control athletes at baseline and with activity and red lines represent the mean values for head impacted athletes at baseline and after head impact during activity. P-values are for the difference in the change in blink parameter between rest and activity between Control and Head Impacted athletes.

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