D2 Measurement of High Temperature and High Humidity Moisture Effects in Football Helmet Elastomeric Energy-Absorbing Padding Performance and Implications for Head Injury Danger

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After attending this presentation, attendees will better understand a method for improved scientific evaluation and certification of a football helmet head-impact potential when used in common, but not currently tested, conditions of both high temperature and humidity.

Certification and evaluation of new and reconditioned football helmets should include impact performance evaluations under high temperature and high humidity soak conditions that more realistically replicate early season environmental use conditions. This presentation will impact the forensic science community by explaining how this type of evaluation can be beneficial in forensic science studies and in early phases of helmet design, and in reconditioning of used helmets, so as to assist in the proper selection of energy-absorbing padding that is more resistant to degradation of impact safety performance in the high temperature and high humidity environment.

Publicity on the dangers of concussion and severe head injuries sustained by football players subjected to repetitive head impacts has, rightfully, received much attention in recent years, in a very large part due to the diligent work by medical researchers such as Omalu and McKee; however, there is an important contributing factor related to football head injury, caused by repetitive head impacts, that has received virtually no attention thus far except for the research findings presented in this study.[1,2] That factor deals with understanding the degradation of the energy-absorbing impact characteristics of elastomeric padding materials, used in football helmets, when a player is subjected to head impacts while wearing the helmet during common situations involving both high temperature and high humidity moisture conditions, such as the conditions likely to be experienced earlier in the season when the weather tends to be both hot and humid. Current football helmet performance test certification procedures, such as the National Operating Committee on Standards for Athletic Equipment (NOCSAE) standard, do not have and never have had a test criterion for measuring helmet impact Severity Index (SI) performance when simultaneously subjected to both high temperatures and high humidity above the 90% relative humidity level.[3] The current criteria only require testing with humidity in the range of 25% to 75% levels.

In this study, two types of football helmet elastomeric Energy-Absorbing (EA) forehead impact pad designs were tested Quasi-Statically (QS) and dynamically for evaluation of load-deformation performance and head impact severity when subjected to two different environmental conditions. One environmental series of tests were run with the pads and helmet tested at ambient conditions of 23oC (72oF) and 70% humidity. A second series of tests were run with the pads and helmet subjected to a three-hour soak at 42oC (108oF) and 93% humidity. Both types of EA pads were designed in a "dual density" configuration (i.e., soft foam near the forehead and stiffer foam at the shell side), with the exception that one type of pad was encased in a Vinyl Cover (VC) and the other type had No Vinyl Cover (NVC). Both new and used pads were tested. The EA pads were 2.54cm thick and were compressed to just over 60% of full thickness in the QS tests. The QS tests showed a dramatic drop in load-carrying capability of the forehead pad when tested at the high temperature and humidity condition (see below plot). The result of this "softening" of the pad is that it becomes easier for the helmet pads to "bottom out," leading to much higher impact-load transfer to the head of the athlete.

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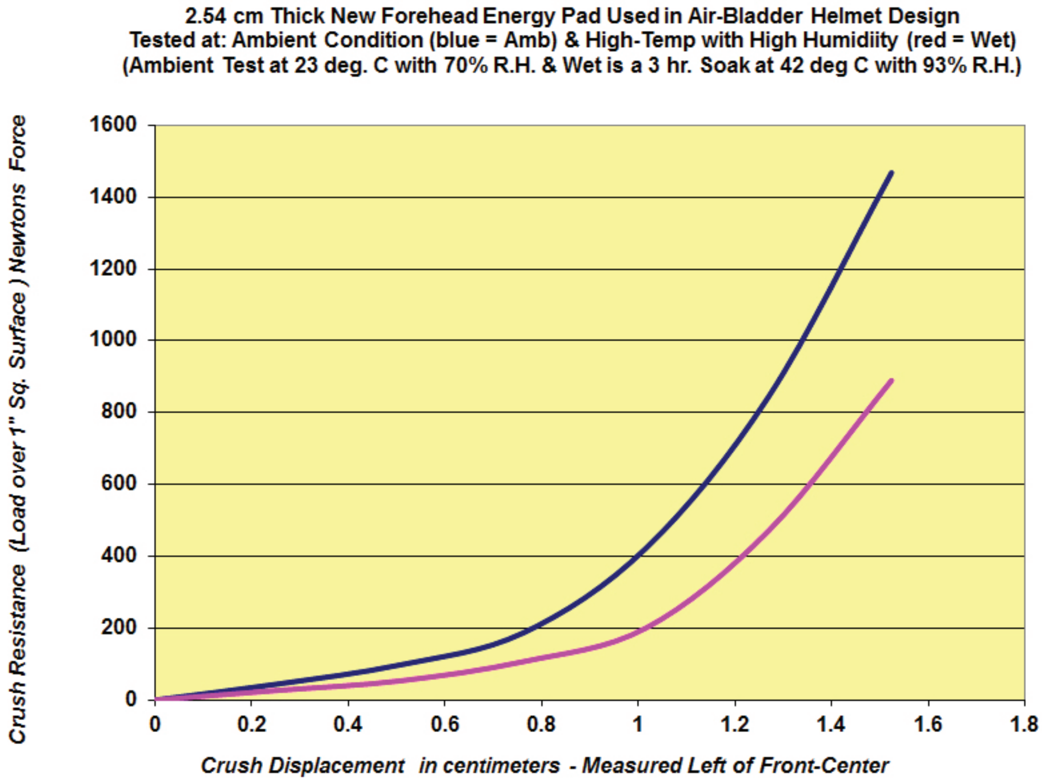

In addition to the QS EA pad testing, dynamic full-helmet drop-impact tests were also conducted for both of the EA pad types and environmental conditions cited above. The dynamic tests used a NOCSAE head-form and vertical drop impacts into the forehead region of the helmet at impact speed levels of 5.54m/s (i.e., 12.2mph), which is the upper speed level required by the NOCSAE, and 19.05m/s (i.e., 14.2mph), which is closer to the speed of a player who can run 40 yards in just over five seconds). For the 5.54m/s impact level, the helmet with the VC forehead EA pad, when tested under the "ambient" test condition, resulted in an accelerometer peak G reading of 141 and an SI level of 645.7; however, when the helmet with the VC pad was then again tested at the same 5.54m/s impact speed, but after conditioning at the Higher Temperature and Humidity (HTH) conditions, the head form accelerometer reading indicated an increased peak G of 163 and an SI level of 786.4, resulting in a more dangerous 22% increase in the SI when tested at the 5.54m/s impact with the HTH condition versus the "ambient" test condition used for helmet NOCSAE certification. When tested with the NVC forehead EA pad at the 5.54m/s impact, the helmet results demonstrated an increase in the acceleration peak G (approximately 175) and SI measures (approximately 900), but no significant difference in the readings between the ambient and HTH. When tested at the 19.05m/s impact level, the peak G's increased, as expected, and the SI measures also increased up to, and beyond, the NOCSAE standard limit of 1,200 for both environmental conditions and both forehead pad types. It should also be noted that the HTH environmental test temperature and moisture conditions could arise from a player perspiring even if the environment levels are less than the HTH condition.

In summary, the environmentally induced changes in the load-deformation characteristics of the energy-absorbing padding shown in the curve above, and the increase in SI found in the HTH environment helmet testing, suggest that more research and testing should be conducted in the HTH area. Because of the current awareness of the "Concussion-Dangers" associated with football repeated head impact injuries brought to light by researchers such as Omalu and McKee, and because of the fact that many players of all ages play under the conditions of "High Humidity with High Temperature," at least in the earlier part of the season, the importance and need for more testing and certification of helmets under conditions of high temperature with high humidity should be of concern to all.

Reference(s):

1. Omalu B. I. et al. Chronic Traumatic Encephalopathy in a National Football League Player. *Neurosurgery* 57, pp 128-134, July 2005.
2. McKee A. C. et al. Chronic Traumatic Encephalopathy in Athletes: Progressive Tauopathy Following Repetitive Head Injury. *Journal of Neuropathology and Experimental Neurology* 68, pp 709-735, 2009.
3. NOCSAE Test Specification Documents, 001-13m13, 002-13m13 and 004-11m14.

Football Helmet Testing, Head Injury Severity, High Temperature Humidity