Force Attenuation Characteristics of a Variety of Hip Pads and Hip Pad Material – Abstract

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Jeffrey A. Bauer, Ph.D

SUNY Cortland

Introduction:

It has been reported that more than 300,000 Americans fracture a hip each year and with the population aging, that number is expected to continue to rise (1). Beyond the immediate pain and suffering of the injury, the long term prognosis for many is bleak with significantly increased likelihood of death within one year following the fracture compared to age matched controls. (2) There is a growing need for effective methods of preventing hip fractures and efforts to address that need are being made by hip pad manufacturers who have brought to market a variety of devices targeted to the elderly.

This document represents a summary of testing procedures and the final results of a series of product impact testing done on a variety of hip pads which are currently being sold to the general public. Hip pads and raw material used for the hips pads were tested. Results represent findings from samples of ComfiHips®, HipSaver® and SafeHip® AirX™ hip pads, as well as, raw material made by ZoteFoam.

Methods: All testing was conducted at the Biomechanics Laboratory at SUNY Cortland, Cortland, NY. Both drop and pendulum impacting rigs were calibrated prior to the start of testing and were configured to generate consistent (± 1% of desired load) impacts. According to an investigation by Robinovitch et al. (3), impact forces to the proximal femur during lateral, standing falls can range between 5,000-8,000 N. However, others (4) reported impact forces to the proximal femur ranging between 7,031 - 26,517 N when using human subjects. Therefore, depending on the hip model and falling mechanism (orientation of the greater trochanter at the time of impact) used, impact forces to the hip during a fall can range between 5,000 to 26,517N. All pads and materials for this study were tested at impacts of 3000N, 7500N, and 10,000N. All data were collected using a Bertec strain gauge force plate (Model 4060, Bertec Corporation, Columbus, OH). Data were collected at 1000Hz using Peak Motus Measuring System data collection software, with the maximum force transmitted through the pads for each impact recorded. The ratio between the impact load and the recorded value upon striking a pad or pad material was used to determine the impact attenuation value for the trial. All samples were impacted using both drop and pendulum rig configurations (Figure 1 & 2).

Figure 1. Vertical Drop Striker Rig showing the loaded drop striker arm sliding through it a collar supported by a scaffold assembly positioned above the forceplate.

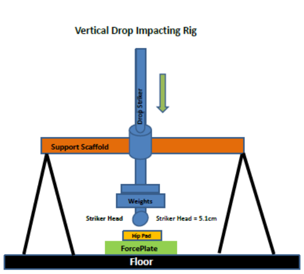
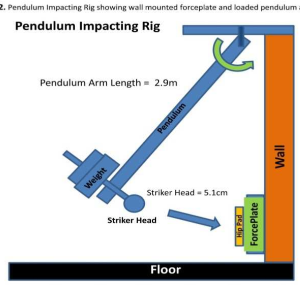
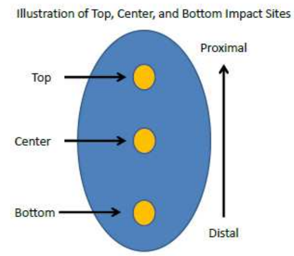


Figure 2. Pendulum Impacting Rig showing wall mounted forceplate and loaded pendulum arm.



Each pad or material sample was impacted 3 times at 3 locations (Figure 3).

Figure 3. Diagram showing the location of the strike points on the hip pads (ComfiHips® and HipSaver®) and raw material tested (Zotefoam). For the SafeHip® AirX™ pad the open notch designed to surround the greater trochanter served at the Center strike location and the pad material located above the notch was designated the top of the pad for testing purposes.



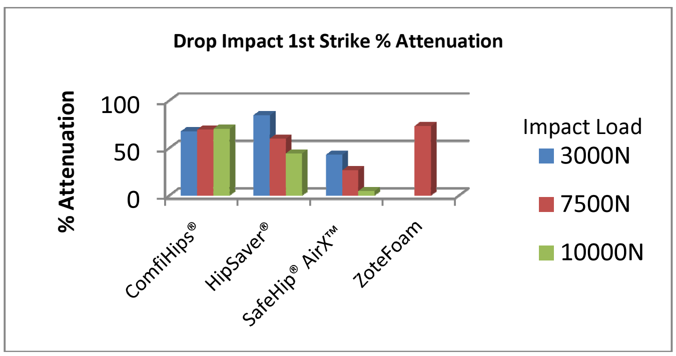
For all pads and material the sequence of impact locations was: test1 = Center, Top, Bottom test2 = Top, Center, Bottom, test3 = Bottom, Top, Center for both the drop and pendulum impact rigs.

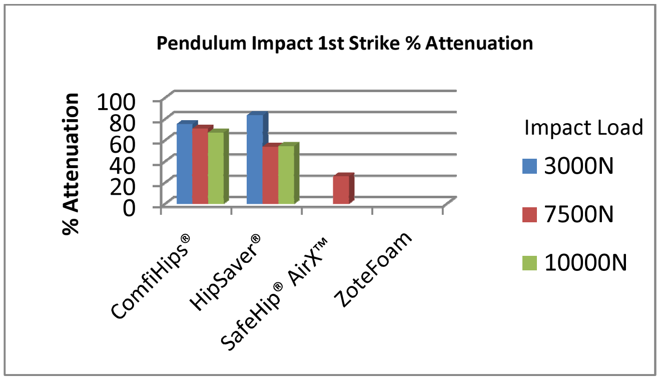
For testing using both impact rigs each impact location was struck 3 times at the same impact level over a 120-150 second interval, then the pad/sample was aligned to the next impact location on the strike plate and testing resumed until a total of 9 impacts per pad/sample were completed. The pad/sample was then labeled and another pad/sample was prepared for testing.

Results: Statistical Analysis of 1st Impact Strike Data

Based on the results of a repeated measures ANOVA analysis comparing all Drop and Pendulum 1st strike data at three impact locations (Top, Center, Bottom) combined across all three impact levels (3000N, 7500N, 10000N) for the 3 hip pads (SafeHip®AirX™, ComfiHips® and HipSaver® and the raw hip pad material (ZoteFoam) it was determined that the ComfiHips® pads were statistically superior ($p < 0.05$) to the SafeHip® AirX™ and HipSaver® Pads in reducing impact forces. The ComfiHips® and ZoteFoam results were not statistically different ($p < 0.05$). The SafeHip® AirX™ pads were statistically different from the ComfiHips®, HipSaver® and ZoteFoam at ($p < 0.05$) indicating that SafeHip® AirX™ performed significantly worse in reducing impact force compared to the other pads and materials tested under both drop and pendulum impact testing conditions.

The following charts represent average percentage of impact force attenuated during 1st strikes at each impact location and impact level for both rig configurations.





Repeated Impact Results:

Each pad/sample tested was impacted three successive times at three locations at specified impact levels of 3000N, 7500N, or 10000N. Analysis of the ability for the HipSaver® and SafeHip® AirX™ pads to attenuate large forces (7500N or larger) more than once was severely compromised after a single strike by the Drop Impact condition. ComfiHips® pads proved to be most consistent in their ability to attenuate force after multiple impacts. It should be noted that manufacturers often recommend that pads be replaced following a single impact of 3000N or greater force. ComfiHips® pads actually increased in the percentage of force attenuated as the impact forces increased during the Drop Impact Combined Strike testing however, while 70.33% of the force was attenuated at the 10000N level, that still resulted in an increase of an additional 350N of force transmitted through the pad when compared to the average measured force at the 7500N level.

Overall the ComfiHips® pads performed better than their competitors during the Drop Impact Combined Strike tests. The SafeHip® AirX™ pad provided virtually no protection at any impact levels tested for center impacts, which corresponded to direct strikes at the anticipated location of the greater trochanter.

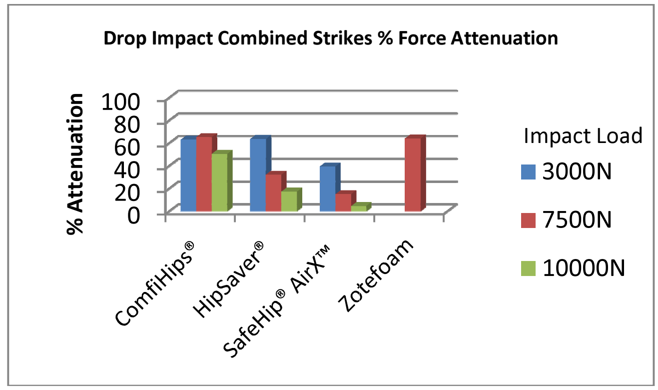
Drop impact testing revealed that the ComfiHips® and HipSaver® pads proved almost identically effective at attenuating impact forces for single impacts of 3000N. The ComfiHips® pad was most effective at both the 7500N and 10000N impact levels. The Zotefoam sample proved to be nearly as effective as the CompfiHips® pad at the 7500N impact level.

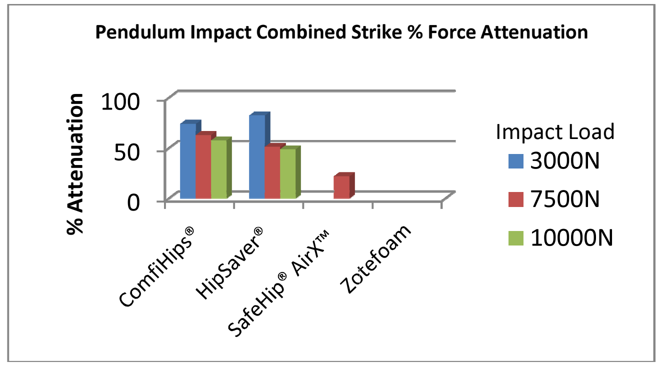
Pendulum impact testing revealed that the HipSaver® pads were most effective at attenuating impact force at the 3000N level. The ComfiHips® Pads were most effective at both the 7500N and 10000N impact levels.

Statistical Analysis of Combined Repeated Impact Strike Data

Based on the results of a repeated measures ANOVA analysis comparing the repeated (3 impacts per location at a given impact level) strike data at three impact locations (Top, Center, Bottom) combined across all three impact levels (3000N, 7500N, 10000N) for the 3 hip pads (SafeHip® AirX™, ComfiHips® and HipSaver®) and the raw hip pad material (ZoteFoam) it was determined that the ComfiHips® pads were statistically superior ($p < 0.05$) to the SafeHip® AirX™, and HipSaver® in reducing impact forces. The ComfiHips® and ZoteFoam material sample results were not statistically different ($p < 0.001$). The SafeHip® AirX™ pads were statistically different from the ComfiHips®, HipSaver® and ZoteFoam at ($p < 0.01$) indicating that SafeHip® AirX™ pads performed significantly worse in reducing impact force compared to the other pads and materials tested under both drop and pendulum impact testing conditions.

The following charts represent average percentage of impact force attenuated during combined strikes at each impact location and impact level for both drop and pendulum rig configurations.





Summary:

A series of impacts were performed using two forms of impacting rigs on several commercially available hip pads and raw material used in such pads. The data from 1st strike and repeated strike impacts revealed significant differences between the force attenuation properties of the various pads and material tested.

Since the pads were not uniform in their ability to attenuate force, there should be an effort made by the industry to standardize testing of all hip pads to ensure that the consumer knows how effective the pad they use is related to its ability to attenuate force and reduce their risk of injury from a fall.

The use of surrogate hip models for impact testing provides value since it is currently impossible to test hip pads on humans to determine how they perform during falls. However, the assumptions made in developing such models are still open for discussion and until everyone agrees on a specific model or models, direct strike impacting will continue to provide the best method of assuring test results can be duplicated by other researchers.

Many factors must be considered beyond just the force attenuation properties of pads when selecting a hip pad, since size, shape, cost, etc. all factor into the compliance of pad usage by at-risk elderly. Future studies about the effectiveness of hip pads should include wear compliance to determine which pads are preferred by consumers.

References:

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2. Vestergaard, P., Rejnmark, L., and Mosekilde, L. (2007). Increased mortality in patients with a hip fracture-effect of pre-morbid conditions and post-fracture complications. 18(12): 1583-1593.
3. Robinovitch, S.N., Hayes, W.C., & McMahon, T.A. (1991). Prediction of femoral impact forces in falls on the hip. Journal of Biomechanical Engineering, 113:366-374.
4. Wiener, S.L., Andersson, G.B.J., Nyhus, L.M. & Czech, J. (2002). Force reduction by an external hip protector on the human hip after falls. Clinical Orthopaedics and Related Research, 398: 157-168.