texas orthopaedic journal®

ORIGINAL RESEARCH

Effects of Using Knee Savers on Lower Extremity Kinematics in Male Collegiate Baseball Catchers During Squatting

Aaron M. Gray, BA; Keith T. Ellison, MD; Brian A. Smith, MD

Department of Orthopaedic Surgery and Rehabilitation
University of Texas Medical Branch, Galveston, TX

ABSTRACT

Introduction: Baseball catchers often experience knee discomfort and pain, which are commonly attributed to prolonged deep squatting. Only one device on the market, knee savers, is described in its advertisements as able to decrease stress and discomfort in catchers' knees.
Methods: We evaluated kinematic effects that knee savers have on the lower extremities during male collegiate baseball catchers' squats.
Results: We found no significant differences in knee flexion angle during squatting with and without the use of knee savers. Further analysis revealed that players whose flexing was shallow—less than 140 degrees—tended to flex deeper with the use of knee savers, whereas players whose flexing was deep—greater than 143 degrees—generally flexed less while using knee savers.
Discussion: Based on our findings, the purported benefits of knee savers have yet to find scientific validation and may represent only the placebo effect.
Keywords: Lower extremity kinematics; Baseball; Knee savers.

INTRODUCTION

Catchers arguably have the most physically demanding position in baseball; the *New York Times* deemed catching the "toughest position" in the game (1). It involves deep squatting or crouching (as referred to by catchers) during each pitch, catching 80+ mph pitched baseballs in men's collegiate and professional leagues, and quickly responding to hits and steals if everything goes right. If things go wrong, catchers may be subjected to pitched or hit ball impacts, person-to-person contact from runners approaching home plate, or a hit by the occasional overswung bat. It is no surprise that discomfort, often affecting the knees, is just part of the game for most catchers. Major League Baseball catcher Russell Martin was observed for a single game to determine

Corresponding Author:
Brian A. Smith, MD
Department of Orthopaedic Surgery & Rehabilitation
University of Texas Medical Branch
301 University Blvd.
Galveston, TX 77555-0165, USA
e-mail: basmith@utmb.edu

DOI: 10.18600/toj.0101.07

how much time he spent crouching. During a single inning, Martin spent 10 minutes 48 seconds crouching and moved up and down 54 times. With these numbers it was estimated that he would have spent 106 hours crouching in games during the 2011 season with 118 starts (1).

Despite many anecdotes regarding knee pain and discomfort among baseball catchers, little has been done to study the short-term and long-term epidemiology of knee injury in this group. According to a study spanning 16 seasons by the National Collegiate Athletic Association (NCAA), 7.5% of all injuries in men's baseball games occurred in catchers (2). That was fourth after base runners, pitchers, and batters, who together sustained nearly 60% of injuries among the nine field positions plus base runners and batters. The same study showed 3.7% of in-game injuries and 3.2% of in-practice injuries to result in internal derangement of the knee, although the percentages of these that occurred in catchers were not reported. Among all injuries, noncontact injuries were the most prevalent. A study based on disabled lists in Major League Baseball throughout seven seasons showed 30.6% of injuries to involve the lower extremity (3). This study as well did not specify catchers as a subgroup of players but did determine that "fielders," defined as all nonpitchers, to include designated batters in the American League, had a higher percentage of total injuries affecting the lower extremity than did pitchers.

Although there is no comprehensive scientific risk or effectiveness documentation, industry has invented and marketed a product targeting baseball catchers with a promise to alleviate knee pain and discomfort. Originally designed by Ali-Med, The Easton Knee Saver (Easton-Bell Sports, Inc., Van Nuys, CA) is a soft wedge device that attaches to the distal posterior aspect of both shin guards. Made of rigid foam, the device offers support intended to limit deep flexion during a crouch as well as provide a larger, softer platform for the catcher to rest upon rather than directly on his or her heels. According to Easton-Bell's website, the device is intended to reduce "stress" on a catcher's knees during a crouch and reduce "erosion of cartilage" (4). It should be noted that in an update to the website, the claim regarding the reduction of erosion of cartilage had been removed (originally accessed on October 23, 2012, and second on July 19, 2013).

The purpose of this study was to determine kinematic effects of knee savers on the lower extremity during a catcher's crouch. To our knowledge, there have been no studies aimed at assessing the effects of knee savers. The null hypothesis was that knee savers would not significantly affect knee flexion angles during a deep crouch.

MATERIALS & METHODS

Experimental Approach

The study used a crossover design. Because it could be presumed that each catcher had a unique crouch in terms of depth, symmetry, and spread, each volunteer served as his own control. Lower limb kinematics were evaluated with 3D motion capture, first without the use of knee savers with the catcher in a deep crouch and second with the use of knee savers with the catcher in a deep crouch. Since no participants had used the product extensively, it was decided to have all volunteers begin the procedures without the knee saver device so that acute use of the device would not affect the natural crouch.

The independent variable for this study was the use (knee saver group) or nonuse (control group) of knee savers; the dependent variable was defined as the knee flexion angle. Hip flexion angle was recorded as a secondary outcome variable.

Subjects

Eleven male collegiate baseball catchers (one retired) were recruited to participate in the study, which was approved by our Institutional Review Board. Active catchers were in the age 18 to 23 years; the retired catcher was 32 years of age. Appropriate written consent was obtained from all volunteers.

Procedures

A two-camera, 30 motion capture system (SIMI Reality Motion Systems, Unterschleissheim, Germany) was used to film the participants and calculate knee flexion angles. The knee flexion angle was defined by markers placed on the greater trochanter, lateral condyle of the knee, and lateral malleolus. The hip flexion angle was defined using the middle of the forehead (as marked on the catcher's mask), greater trochanter, and later condyle of the knee.

Data were gathered over two separate trials performed by each volunteer. Each trial consisted of receiving five pitches while in full crouch for filming of the left and right side (10 pitches total). After each reception the catcher would stand and throw the ball back to the pitcher before returning to a deep crouch, effectively resetting the crouch. The first trial was always performed without knee savers and the second trial with knee savers. Each volunteer had adequately warmed up according to his coach's regimen before commencing the trials.

All angles were calculated as the average of the angles observed during the first three acceptable catches recorded, according to the right or left side. A catch was deemed acceptable when the catcher made minimal to no changes in posture to receive the thrown ball. Catches considered unacceptable for analysis occurred when the volunteer stood or significantly swayed during reception or failed to catch the ball. All angles were taken at the moment of reception.

Statistical Analysis

Means between groups were compared using one-way analysis of variance (ANOVA) for paired data. Simple linear regression was used to assess correlation between knee saver use and nonuse as well as between knee and hip flexion angles. Left and right measurements for each subject were treated as independent, yielding a total of 22 samples. An alpha of 0.05 was used to test for significance in all modalities.

RESULTS

No significant differences were found between the control and knee saver groups in the means of knee and hip flexion angles (Table 1). Control group knee flexion angles plotted against knee saver group angles to assess correlation yielded a significant linear regression with $R^2=0.78$, $p<0.001$, and a slope significantly ($p<0.05$) less than 1 (Figure 1). To better visualize the change in knee flexion with knee saver use, the difference in flexion angles with use was plotted against control group measures (Figure 2). Linear regression of the data yielded $R^2=0.5$, $p<0.0001$, and a slope significantly different from zero ($p<0.0001$).

The data suggest that a subset of players with consistently deeper flexion, greater than 143°, tended to flex less with the knee saver product. In contrast, players in whom flexion was shallower, with angles less than 140°, tended to flex even deeper with the knee saver. The groupings for deep and shallow flexors were determined based on overall group trend above and below naturally occurring cutoff points. Figure 3 shows a representation of this effect in two volunteers, a shallow and a deep flexor. This discrepancy is illustrated quantitatively in Figure 2.

Correlation between knee and hip flexion angles with and without knee saver use was also assessed through linear regression. Figure 4 shows two plots for knee versus hip flexion angles for both nonuse and use of knee savers. The plots yield regression lines that are not statistically different; however, the regression for the controls had much lower variability, standard error (SE)=1.34, than that of knee saver use, SE=4.92 (R^2=0.962 and R^2=0.465, respectively).

Table 1. Comparison of flexion angle between control and knee saver groups.

Angle	Control Mean ±	SD	Knee Saver Mean ±	SD	P Value
Hip	138.92°	7.82	138.16°	5.70	0.358
Knee	114.27°	6.86	113.63°	6.71	0.284

Reported means are for all 22 samples, which include left and right measurements for 11 volunteers.

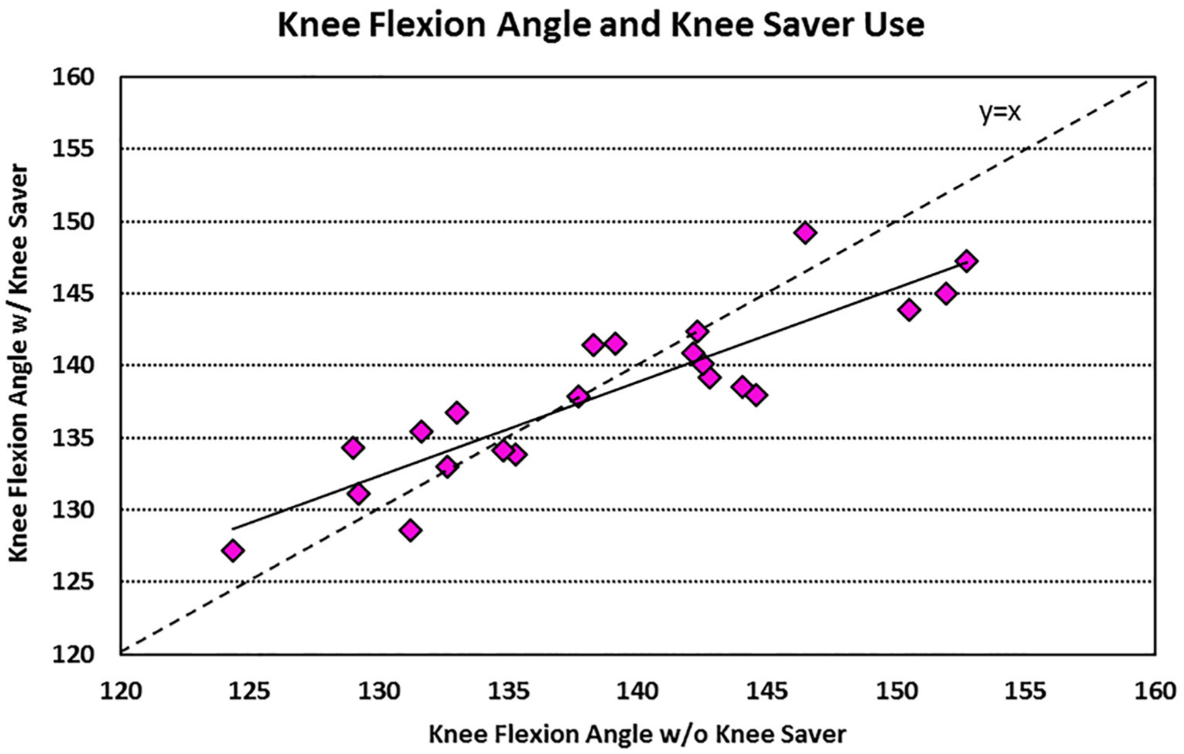


Figure 1. The solid line represents the linear regression computed from the 22 samples. The dashed line represents a “no change” relationship.

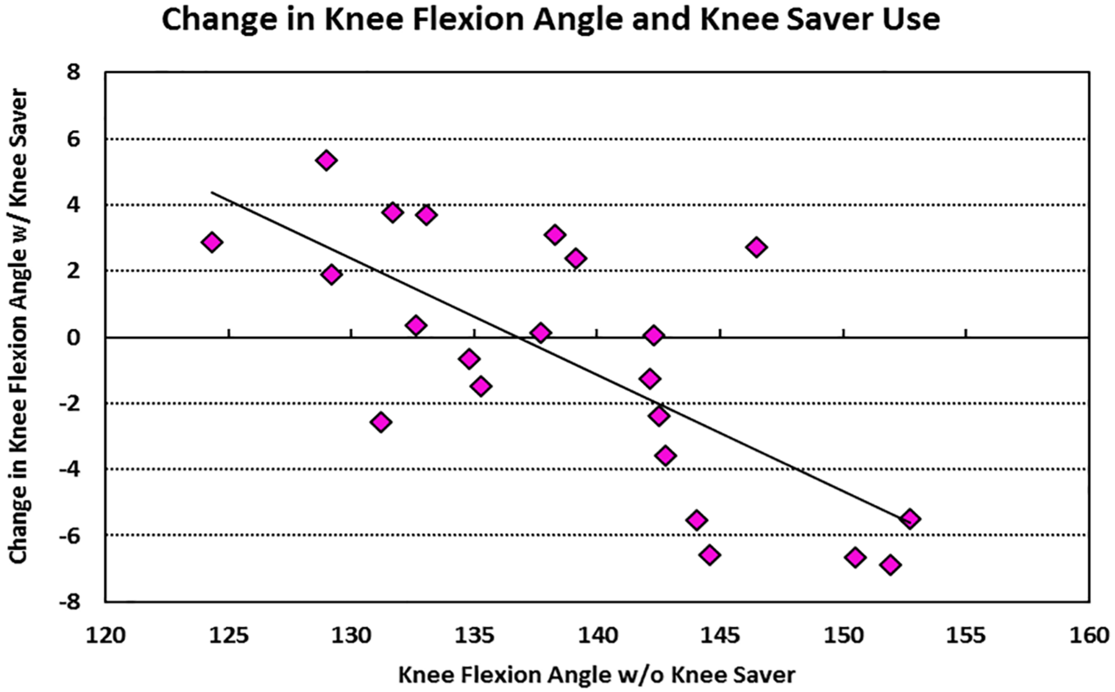


Figure 2. The difference in knee flexion angles between the knee saver and the control groups. The line segment represents linear regression on the samples with R^2=0.5 and p<0.0001.

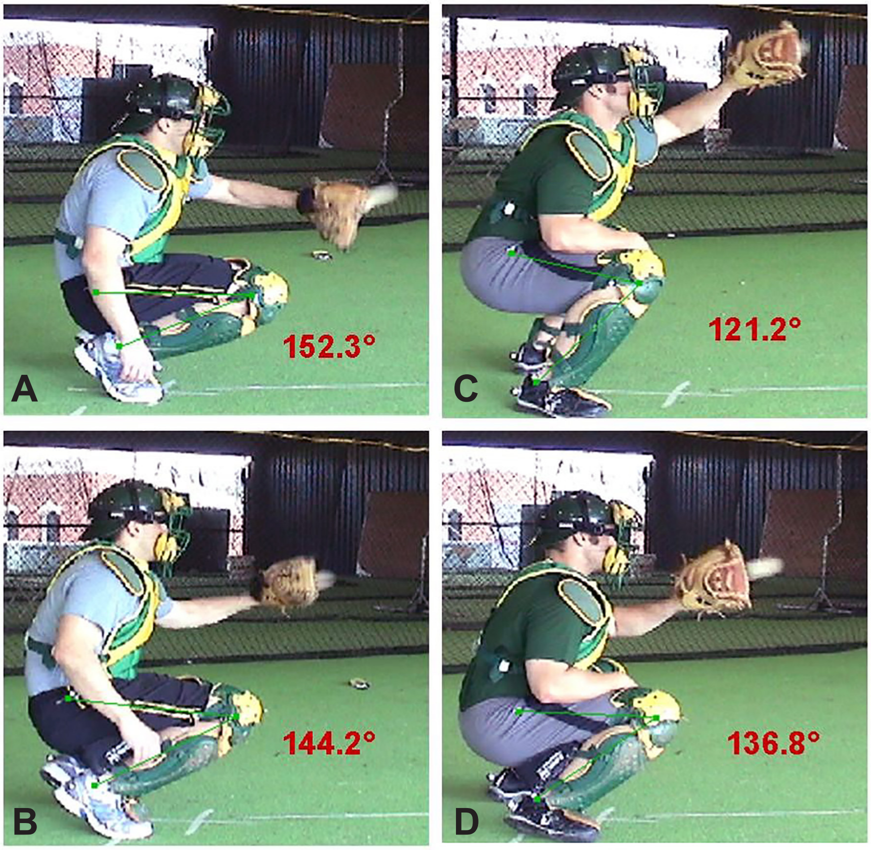
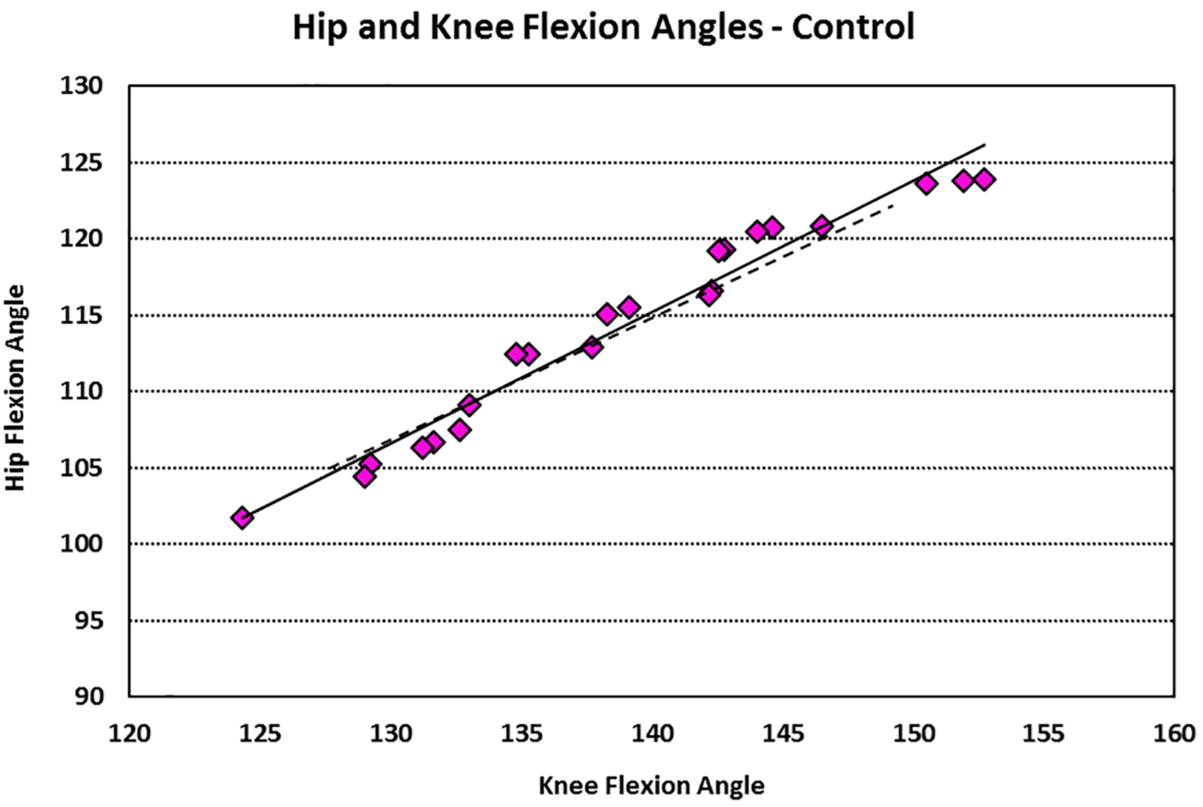


Figure 3. Comparison of a deep-flexing catcher and a shallow-flexing catcher with and without the use of knee savers. A deep knee-flexing catcher before (**A**) and after (**B**) using knee savers; a shallow knee-flexing catcher before (**C**) and after (**D**) using knee savers. In image C, the catcher appears catching the ball high, but there was no movement from crouch to make this catch.



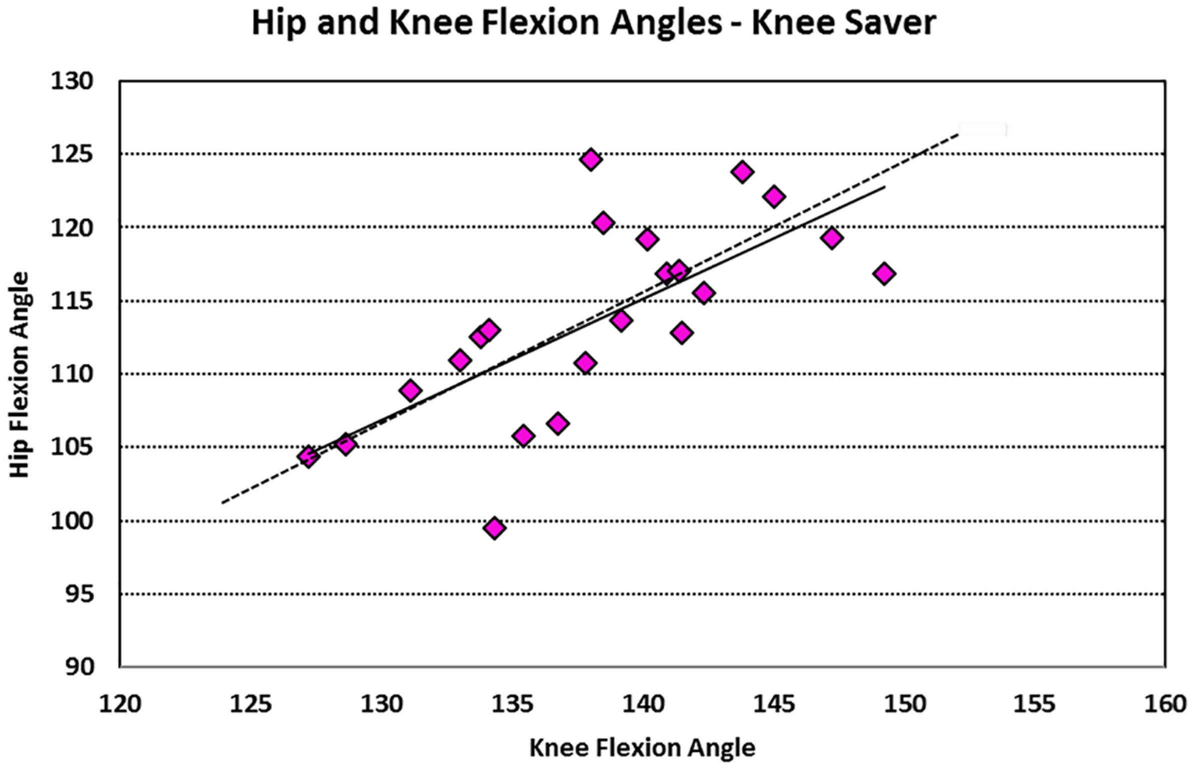


Figure 4. The solid lines represent linear regression on the data presented in the respective chart. The dashed lines represent linear regression on the data presented in the other chart. The two regression lines are not statistically different, but each regression is significant, with $p<0.001$. Correlation coefficients were $R^2=0.962$ for control, and $R^2=0.465$ for knee saver. Standard errors were 1.34 for control and 4.92 for knee saver.

DISCUSSION

The purpose of this study was to observe the effects of knee saver use in male collegiate baseball catchers on lower extremity kinematics during a deep crouch. The results demonstrate that knee saver use did not significantly decrease knee flexion during a deep crouch, failing to reject the null hypothesis. Under certain circumstances, notably those volunteers with greater knee flexion before knee saver use, knee flexion angles were increased with the knee saver product. Although knee savers reduced deep flexion in a subset of catchers, the difference is likely not clinically significant. Prolonged squatting has been demonstrated to be a risk factor for meniscal injury and possibly osteoarthritis (5,6). The posterior horns of the menisci become impinged between the femur and tibia during deep flexion, potentially leading to injury over repetitive insult (7,8). According to Williams and Logan (8), flexion beyond 120° causes the medial femoral condyle to rise and move onto the posterior horn of the medial meniscus. Because of a lack of mobility of the posterior horn, the meniscus appears to be vulnerable to damage (9-12). All of our volunteers flexed well past 120 degrees and the knee saver device was unable to reduce flexion beyond this threshold. If deep squatting carries an inherent risk for meniscal injury, knee savers will not significantly decrease that risk unless they decrease the load on the knee joint through other mechanisms and that decreased load has an effect on meniscal impingement.

At one time the claim was made that knee savers can reduce the damage done to cartilage caused by prolonged and frequent crouching (4). A predisposition to osteoarthritis from deep squatting has been documented (5,13). Recent work by Hartmann et al. (6), however, demonstrated that deep squatting places less load on the knee joint than does quarter squatting or half squatting, with squatting at 90 degrees incurring the highest retropatellar compressive forces. These effects are due to the "wrapping effect," functional adaptation, and soft tissue contact between the posterior thighs and calves. The wrapping effect occurs when flexion exceeds 90 degrees and is defined as a support comprising contact between the intercondylar notch and quadriceps tendon that results in decreased knee joint forces (14). Furthermore, contact between the soft tissues of the calves and posterior thighs acts to decrease knee joint forces beyond 130 degrees of knee flexion (15). In this regard, a knee saver device may assist in further reducing knee joint forces by increasing the contact area between the posterior thigh and calves, ensuring maximal unloading of the knee joint; this could explain why some of our volunteers experienced deeper squatting with the knee saver.

Contrary to popular belief that deep squatting is to blame for acute knee pain and long-term injury in baseball catchers, current literature suggests that deep squatting is protective of knee joint articular cartilage compared with quarter squatting and half squatting. We speculate that knee discomfort experienced by catchers is not a function of time spent squatting, but rather the abundant transitions through high knee joint load states when moving from standing to deep squat, and vice-versa, that a catcher experiences throughout a game and practice. If true, knee saver devices do nothing to affect the maximal knee joint forces incurred by catchers. Research is warranted to determine whether multiple complete motions through a squatting maneuver or prolonged squatting without vertical motion causes more knee joint discomfort. This study also showed an increased variability in the correlation of knee and hip flexion angles with the use of knee savers (Figure 4).

This result potentially indicates a disruption in the natural biomechanics of deep squatting, the implications of which are unclear. It has been shown, however, that squatting increases lumbar spine compressive forces beyond those of the true weight load (16). The increased variability in hip flexion angle may act to decrease or increase lumbar compression because the spine must adapt to keep the catcher in an effective position. Further speculation on the subject is beyond the scope of this manuscript.

Limitations in this study may serve as a roadmap for future efforts in assessing knee joint discomfort and injury in baseball catchers. Quadriceps and hamstring activation both affect knee joint forces and studying them with electromyography during a deep squat with and without knee saver devices is warranted. Further, quantitative load forces between the posterior thigh and calf, as well as between the buttock and knee saver, would greatly assist in defining the true efficacy of the product.

PRACTICAL APPLICATIONS

Each addition of comfort or safety equipment to a catcher's uniform comes with a penalty to agility or speed. The decision to use a knee saver device appears to be a tradeoff between blunted mobility and the promise of decreased "stress" and discomfort on the knee joints. Based on our study, the knee saver devices do not decrease knee flexion enough to prevent potential meniscal injury, which would require reduction to below 120°. Further, although we did not take force measurements with the knee saver device, natural biomechanics are already at work to decrease knee joint forces during deep squats through the wrapping effect, functional adaptation, and soft tissue contact and loading through the posterior thigh and calf. It appears from our results that the risk that knee savers would in themselves harm an athlete physically is minimal. However, the purported benefits have yet to find scientific validation and may only represent the placebo effect.

REFERENCES

1. Waldenstein D. Russell Martin Plays Catcher, the Toughest Position in Baseball. New York Times, June 16, 2012. http://www.nytimes.com/2012/06/17/sports/baseball/russell-martin-plays-catcher-the-toughest-position-in-baseball.html?pagewanted=all. Accessed July 22, 2014.

2. Dick R, Sauers EL, Agel J, Keuter G, Marshall SW, McCarty K, McFarland E. Descriptive epidemiology of collegiate men's baseball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003- 2004. J Athl Train. 2007;42:183-93.

3. Posner M, Cameron KL, Wolf JM, Belmont PJ Jr, Owens BD. Epidemiology of Major League Baseball injuries. Am J Sports Med. 2011;39:1676-80.

4. Easton Sports. Knee Saver II Product Description. http://www.eastonbaseball.com/knee-saverii-by-alimed-2339.html. Accessed October 23, 2014.

5. Atkins JB. Internal derangement of the knee joint in miners. Br J Ind Med. 1957;14:121-6.

6. Hartmann H, Wirth K, Klusemann M. Analysis of the load on the knee joint and vertebral column with changes in squatting depth and weight load. Sports Med. 2013;43:993-1008.

7. Nakagawa S, Kadoya Y, Todo S, Kobayashi A, Sakamoto H, Freeman MA, Yamano Y. Tibiofemoral movement, 3: full flexion in the living knee studied by MRI. J Bone Joint Surg Br. 2000;82:1199-200.

8. Williams A, Logan M. Understanding tibio-femoral motion. Knee. 2004;11:81-8.

9. Thompson WO, Thaete FL, Fu FH, Dye SF. Tibial meniscal dynamics using three-dimensional reconstruction of magnetic resonance images. Am J Sports Med. 1991;19:210-5.

10. Tienen TG, Buma P, Scholten JG, van Kampen A, Veth RP, Verdonschot N. Displacement of the medial meniscus within the passive motion characteristics of the human knee joint: an RSA study in human cadaver knees. Knee Surg Sports Traumatol Arthrosc. 2005;13:287-92.

11. Vedi V, Williams A, Tennant SJ, Spouse E, Hunt DM, Gedroyc WM. Meniscal movement. An in-vivo study using dynamic MRI. J Bone Joint Surg Br. 1999;81:37-41.

12. Yao J, Lancianese SL, Hovinga KR, Lee J, Lerner AL. Magnetic resonance image analysis of meniscal translation and tibio-menisco-femoral contact in deep knee flexion. J Orthop Res. 2008;26:673-84.

13. McMillan G, Nichols L. Osteoarthritis and meniscus disorders of the knee as occupational diseases of miners. Occup Environ Med. 2005;62:567-75.

14. Bandi W. [Retropatellar kneejoint lesions. Pathomechanics and pathological anatomy, clinical picture and therapy]. [Article in German] Aktuelle Probl Chir Orthop. 1977;4:1-94.

15. Zelle J, Barink M, Loeffen R, De Waal Malefijt M, Verdonschot N. Thigh-calf contact force measurements in deep knee flexion. Clin Biomech (Bristol, Avon). 2007;22:821-66.

16. Cappozzo A, Felici F, Figura F, Gazzani F. Lumbar spine loading during halfsquat exercises. Med Sci Sports Exerc. 1985;17:613-20.