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DIFFERENCE OF COMPARESSION-DISPLACEMENT AMONG BASEBALLS WITH DIFFERENT WOOL PERCENTAGE

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SUMMARY
The purpose of this study was to compare the characteristic of compression-displacement among baseballs with different wool percentage yarn. 60 customer-design baseballs were produced with 15%, 30%, 50%, 85% and 90% woolen yarn under the same material and manufacture procedures. The baseball's diameter and compression-displacement were measured in conditioned lab. Results reveal that 85% and 90% baseballs have significant lower compression force than those of 15%, 30% and 50% baseballs. Both 85% and 90% baseballs have significant smaller deformation than that of 15% baseball. It concluded that a baseball with higher wool percentage, above 85%, showed softer and larger deformation recovery compared to those with lower wool percentage. The wool percentage in a baseball is crucial material component for stiffness and characteristic of compression-displacement.

INTRODUCTION
Accord to rule-1.09 in official baseball rule, the ball shall be a sphere formed by yarn wound around a small core of cork, rubber or similar material, covered with two strips of white horsehide or cowhide, tightly stitched together. The majority part of a baseball is the center of the ball which shall be produced by winding three layers of woolen yarn and one layer of poly/cotton yarn around the core center. The three layers consists of 4-ply gray woolen yarn containing approximately 85% wool and 15% other fibers. However, there are different wool percentage baseballs in market such us game ball, practice ball or little league ball. It's not clear that wool percentage in baseball affect on the characteristic of compression-displacement. Therefore, the purpose of this study was to compare the characteristic of compression-displacement among baseballs with 15%, 30%, 50%, 85% and 90% woolen yarn.

METHODS
60 customer-design baseballs, 12 baseballs each model, were produced with 15%, 30%, 50%, 85% and 90% woolen yarn under the same material and manufacture procedures by Tayang Sporting Corp., Taiwan. All baseballs were stored at 22±2℃ and 50% relative humidity for at least two weeks prior to measurement. The baseball's diameter and compression-displacement were measured in conditioned lab. The vernier was used to measure baseball diameter before and after compression. The deformation was defied as difference between diameter before and after compression. The testing of compression-displacement was showed as Figure 1. The standard method for measuring the compression-displacement, ASTM 1888-09, was used in this study. The baseball was placed between two flat-plate surfaces of a compression machine and then compressed to a standard displacement of 6.35-mm in 15 s at a constant rate and record the peak force applied at that level of displacement. Then baseball was rotated the 90° and repeat the above measurement procedures. Compression force was calculated as the average of the two measured forces required to compress the test ball 6.35 mm on two different axis of the ball. The static compression-displacement of a baseball was a mechanical property which can correlate to dynamic properties. It can be use for purposes of consistency of performance.

Figure 1: Experimental testing set-up

RESULTS AND DISCUSSION
Figure 2 showed that compression force changed by displacement for a representative baseball sample of each model. After analysis of independent sample one-way ANOVA, results reveal that both 85% and 90% baseballs have significant lower compression force than those of 15%, 30% and 50% baseballs ($p<.05$). Both 85% and 90% baseballs have significant smaller deformation than that of 15% baseball ($p<.05$). However, diameters showed no significant difference among baseballs with different wool percentage ($p>.05$).
The finding showed that a baseball with higher percentage woolen yarn is lower stiffness, softer, baseball and larger deformation recovery compared to those with lower wool percentage. During bat-ball impact, a baseball is compressed

to 50% of its original diameter [1]. The majority part of a baseball which winds woolen yarn around the core center would be a critical component in bat-ball impact. To our knowledge, this is the first study to investigate wool percentage of a baseball. Some static properties of baseballs have been correlated with ball impact characteristics, particularly peak force and stiffness [4]. Previous studies indicated that increased compression force has also been linked to decreased deformation during impact, increased stress transmitted to bone and increased chance of and severity of head injury [3]. A decreased 15-20% hardness baseball for teenage player would be decrease severity of head and eye injury [5]. Crisco et al. demonstrated that decreasing baseball stiffness by a factor of 15 decreased peak impact force by 66% [2]. The study found that 85% and 90% baseballs are softer due to lower compression force. Therefore, the wool percentage in a baseball is crucial material component for stiffness and characteristic of compression-displacement.

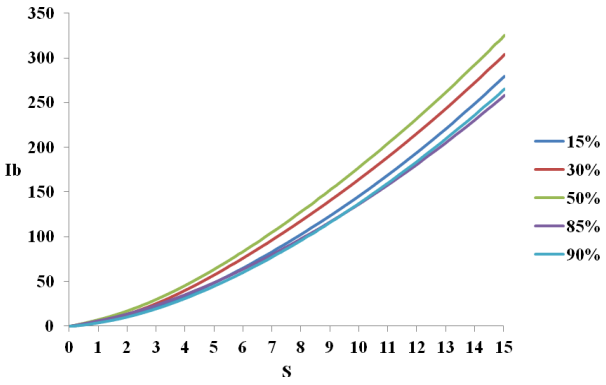

Figure 2: Compression force and displacement relationship of a representative baseball sample of each model.

CONCLUSIONS

The major finding of this study was that a baseball with higher wool percentage, above 85%, showed softer and larger deformation recovery compared to those with lower wool percentage. Therefore, the wool percentage in a baseball is crucial material component for stiffness and characteristic of compression-displacement.

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Table 1: Comparison of compression force, diameter and deformation among baseballs with different wool percentage.

	Compression force (lb)	Diameter before compression (cm)	Diameter after compression (cm)	Deformation (cm)
15 %	321.76±11.13	72.86±0.22	71.49±0.17	1.37±0.20
30%	329.36±14.57	72.72±0.27	71.43±0.24	1.29±0.26
50%	320.56±15.60	72.81±0.27	71.52±0.29	1.29±0.17
85 %	279.40±10.60*	72.56±0.21	71.51±0.18	1.05±0.24+
90 %	295.68±17.78*	72.36+±0.30	71.32±0.27	1.04±0.14+

* showed that 85% and 90% baseballs have significant lower compression force than those of 15%, 30% and 50% baseballs.
+ showed that 85% and 90% baseballs have significant smaller deformation than that of 15% baseball.