THE THROWING PERFORMANCE AND TRUNK KINEMATICS OF QUARTERBACKS DURING A FOOTBALL THROW WHILE WEARING RIB PROTECTOR GARMENTS

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The purpose of this study was to determine if hard and soft rib protector garments have an effect on trunk kinematics and throw performance (accuracy and speed) of experienced quarterbacks during an overhand football pass. Eight quarterbacks completed 10 throws during each of three rib protector conditions (no rib, soft, hard). Protector conditions were compared using non-inferiority testing. None of the rib protectors displayed performance or kinematics conclusively inferior to the control condition. However, the CIs of the rib protectors for two variables overlapped the non-inferiority margin. In addition, among individual participants, mixed results were demonstrated. Overall, for performance and kinematics, we recommend the soft rib protector, as it did not negatively affect any throw performance variables analyzed.

KEYWORDS: passing, spine, mobility, speed, accuracy, non-inferiority

INTRODUCTION: Rib protectors are not mandatory equipment in American football but could prevent or reduce the severity of injuries in the trunk area, such as fractured ribs, splenic lacerations or kidney injuries, specifically in skilled players who are often tackled (Al-Hassani et al., 2010, 2013). Due to changes in the professional and collegiate American football leagues' rules implemented in 2010, players in a game setting may not tackle players not prepared for a hit above the shoulders or block below the waist (Redding, 2012). This puts the trunk area of offensive players at higher risk of sustaining high collision impacts than previously. Rib protectors could benefit quarterbacks, because they handle the ball every offensive play. Particularly, when waiting to pass, they are in an upright throwing position that leaves the lower trunk vulnerable to unanticipated hits. To throw effective passes, they must rotate the trunk axially without mechanical restriction, as trunk rotation has been shown to play an important role (Fleisig, Barrentine, Escamilla, & Andrews, 1996). Therefore, if players perceive that rib protectors could reduce their trunk mobility and athletic performance, some will not wear them. However, no evidence of rib protectors' effects on these factors exists.
Rib protector systems have foam padding or some type of protective plastic sewn into a specialized compression shirt. It is not yet known whether stiffness of the protector restricts trunk motion. Hence, the purpose of this study was to determine if a soft or hard rib protector garment would have an effect on axial trunk kinematics and throwing performance of quarterbacks during an overhand football throw.
We predicted that, compared to wearing a compression shirt with no rib protector (NO-RIB), both a compression shirt with a soft foam rib protector (SOFT-RIB) and a compression shirt with a hard plastic plated rib protector (HARD-RIB) would not produce reduced axial trunk kinematics and throw performance. Particularly for HARD-RIB, mechanical restriction was expected to affect values, but the differences would be so slight as to be within the range of natural variability of throwing. Additionally, as shown for other sportswear (e.g., footwear, lower-leg compression sleeves), individual participants biomechanically respond differently to equipment/apparel (De Wit, De Clercq, & Aerts, 2000; Stickford, Chapman, Johnston, & Stager, 2015). Therefore, it is also important to understand rib protector influences on individual participants.

METHODS: Eight males (age: 23.7 ± 4.4 yr; height: 178.26 ± 3.46 cm; mass: 87.24 ± 7.91 kg) with competitive quarterback experience (high school varsity to professional) performed 10 single-step, drop-back football passes as quickly and accurately as possible to a 45 cm diameter target located 9.1 m away for each rib protector condition (NO RIB, SOFT-RIB, HARD-RIB) in a counterbalanced order. For upper and lower trunk spatial locations, the base of each plastic rod cluster of 4 reflective markers (9 mm) (Figure 1) were placed on the skin over T8 and on L3, respectively, and the adjoining rod fed through a small hole (3mm dia.) in the compression material of the rib protector garment.

Figure 1. Plastic rod reflective marker cluster for trunk kinematics.

One 14mm reflective marker, placed on the throwing hand's 2nd metacarpal head; and two placed on the ball were used later to identify critical events.
Marker locations were captured using a 7-camera Vicon MX-40™ motion capture system (240 fps, Vicon Motion Systems Ltd., UK). Vertical ground reaction force signals for the back foot (Bertec platform 4060-NC, 1200 Hz) were used later to determine the beginning of the phase of interest. Throw error (distance from target center) and ball speed (Bushnell® radar gun) were recorded. The axial angle (Z) of upper trunk relative to lower trunk (Cardan angle, sequence: XYZ) was used to derive variables of peak axial trunk displacement, velocity, and acceleration. The participant's top five throws (composite score of throw error and ball speed) for each condition were analyzed. Non-inferiority testing of a variable for a given rib protector compared to NO-RIB began by expressing the variable as a 'treatment difference' to generate the 95% confidence interval (95% CI) (Vavken, 2011). 'Non-inferiority' of the rib protector was concluded if entire CI was in the range from the non-inferiority margin (NIM) and beyond in the 'more favorable direction' (e.g., higher ball speed); 'inferior' if the CI was entirely in the 'less favorable' region; and 'inconclusive' if the CI crossed NIM. NIM of one standard deviation (SD) of NO-RIB was chosen as a conservative boundary to represent the typical variation of throwing. The same technique was applied to individual participant data, using the participant's standard deviation. Aposteriori, throw error and accuracy of all trials were correlated to angular variables ($p < .05$) to confirm whether the axial trunk kinematics did potentially influence performance.

RESULTS: All group variables were non-inferior for both rib protectors (Figure 2), except for three results. HARD-RIB's 95% CI extended into the direction of greater throw error than NO-RIB. Both rib protectors' lower 95% CI bound was less than NIM for peak relative angular displacement. All 95% CI also included the zero difference value. The spread of the 95% CIs for both rib protectors for peak axial angular displacement were large (SOFT-RIB: 29.19°, HARD-RIB: 26.04°) but were centered at approximately zero treatment difference.
Most individual participant outcomes were consistent with group outcomes. Few individual participants responded negatively to either rib protector (Figure 3). One participant showed inferiority for throw error during HARD-RIB; another for ball speed during SOFT-RIB. At least one, sometimes two participants, displayed inferiority for any given axial trunk variable. Qualitatively, across all variables, greater numbers of participants displayed non-inferiority for the SOFT-RIB compared to the more inconclusive HARD-RIB.
Groupwise, accuracy and trunk displacement were not significantly correlated (r = -.073, p =.435). However, for ball speed, there were weak positive correlations with trunk axial velocity and acceleration (r = .302, .295, respectively; p <.01).

DISCUSSION: We suggest that the rib protectors, particularly SOFT-RIB, likely had minimal rotational or performance effects. Nearly all group results showed that neither rib protector was inferior to NO-RIB for throw performance and trunk kinematics. Ball speed was correlated with greater axial velocity and acceleration but was not decreased by rib protectors, suggesting that passing quickness and speed is not affected. Also, most 95% CI were within the conservative NIM of 1 SD and nearly centered at zero differences.

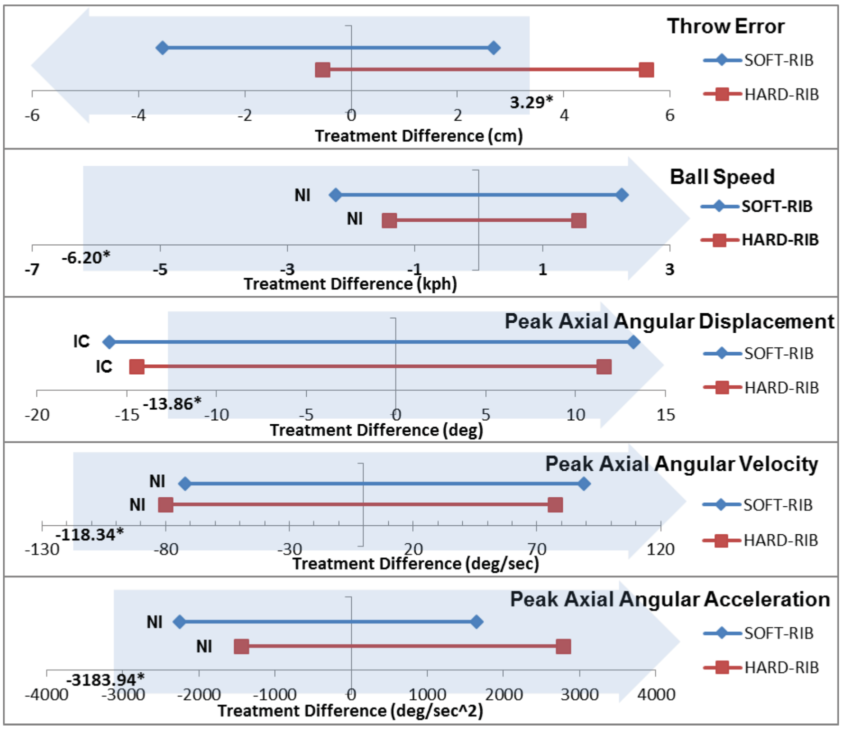

Figure 2. Outcomes of group non-inferiority testing. Thin lines show 95% CI of treatment difference (protector – no-rib) for each rib protector. Large arrow represents the non-inferior range: tail is boundary at the non-inferiority margin (value in by bold text and * below X axis) and continues infinitely in the more 'favorable' difference direction. NI = non-inferior to NO-RIB and IC = inconclusive.

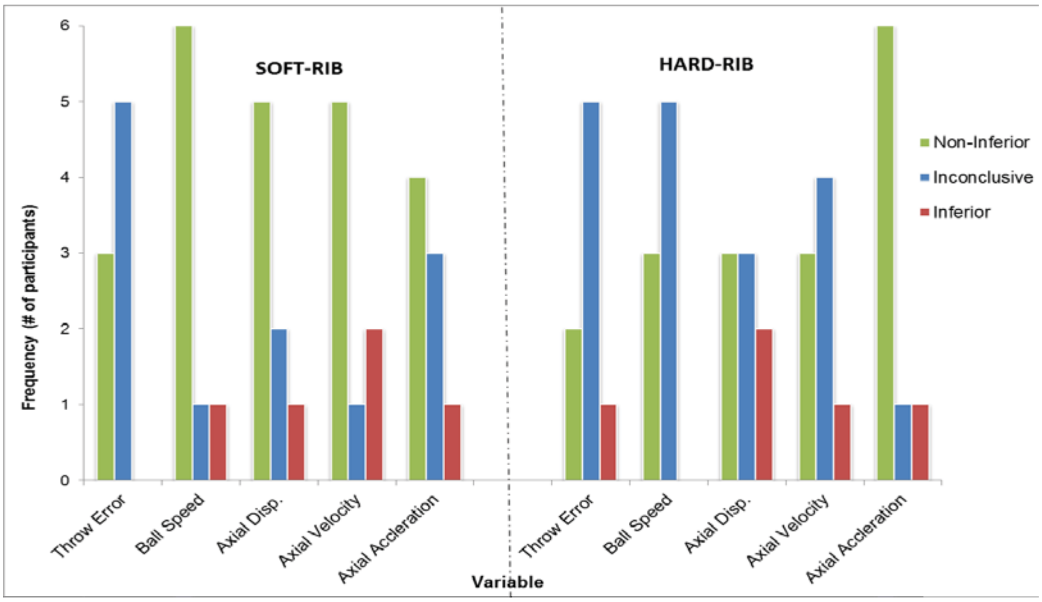

Figure 3. Frequencies of individual participant non-inferiority testing outcomes.

However, axial displacement and throw error were more inconclusive. HARD-RIB tended to decrease trunk displacement and increase throw error. However, throw error difference was less than 6 cm for the 95% CI upper bound. This is far less than the hand size of the person catching the ball and likely not behaviorally meaningful.
To our knowledge, no football throwing studies exist that quantified the biomechanical effects of rib protection (or other sports equipment). However, our outcomes are similar to those of a

study by Roach and Lieberman (2014) who observed that a full-torso rigid brace worn during baseball pitching displayed no statistical differences for torso angular velocity or acceleration phase timing; or pitch accuracy, but a slight but significant difference in ball speed (~3.5 kph). Thus, our less rigid braces likely have little effect on axial trunk kinematics and throw performance.

Individual participant responses were similar but more inconclusive than group outcomes. Only one or two individuals for a given rib protector and variable exhibited inferiority, suggesting most individuals were not adversely affected by a rib protector, but some individuals respond differently to the rib protectors. Interestingly, congruent with group variability measures, intra-participant variability was the greatest for the NO-RIB condition for most participants. This may be due to a lack of motion constraint, sensory input or novelty that rib protectors may provide.

One limitation at present was slightly insufficient sample size. However, 3/5 variables had sufficient inferiority test power. Second, a conservative NIM of 1 SD was used because no relevant known sizes of behaviorally-meaningful differences exist. Third, the compression shirt of control and hard-rib conditions was different than the soft-rib shirt, as protectors are the commercially available products. However, the overall stiffness properties of both compression garments were very similar(Walker, 2017).

CONCLUSION: The effects of wearing a rib protector on throw performance and trunk axial kinematics appear to be very small, particularly for SOFT-RIB. As negative effects of HARD-RIB were limited primarily to a small number of participants, most athletes could use either protector without performance decrements. More investigation is necessary to determine how performance is affected in an actual game setting. Although injury prevention efficacy of either hardness protector is not yet known, the potential benefits of wearing a rib protector may outweigh possible performance costs.

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