POWER UP THE SWING: A BIOMECHANICAL STUDY TOWARDS A GOLF EXOSUIT

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This biomechanical study investigates the impact of a passive elastic exoband on golf swing performance, focusing on optimizing the timing and magnitude of its stretch to increase the clubhead velocity. We analyzed the performance of two professional golfers wearing the exoband in four configurations. Our findings suggest that pre-stretching the exoband during the backswing, coupled with an optimal X-factor, significantly increases clubhead velocity by efficiently releasing stored elastic energy. Notably, the configuration pulling the left posterior shoulder towards the left ASIS resulted in the highest clubhead velocity and greatest exoband contribution, demonstrating the importance of optimal stretch and energy transfer for maximizing swing power. This study paves the way for future exosuit designs in golf to harness elastic energy and revolutionize swing mechanics.

KEYWORDS: Golf swing, X-factor, elastic exoband, clubhead velocity, mechanical work.

INTRODUCTION: The relentless pursuit of power in golf has led to the exploration of various techniques and technologies. Among these, the investigation of exosuits and exobands could be fascinating for their potential to augment clubhead velocity as one of the determinants of golf swing performance. This study delves into a crucial element of exoband-aided performance: the X-factor and its stretch during the golf swing.

The X-factor refers to the rotational separation between the hips and shoulders during the backswing, with a larger angle indicating greater potential for stored elastic energy. The subsequent X-factor stretch in the downswing involves utilizing this stored energy to generate explosive swing and clubhead acceleration. Many studies have identified this stretch as a critical determinant of clubhead velocity (Cheetham et al., 2001; Cole & Grimshaw, 2009; Joyce, 2017), with elite golfers demonstrating a pronounced ability to “exploit” the X-factor for increased power (Cole & Grimshaw, 2009).

Driven by the pivotal role of the X-factor stretch in clubhead velocity, researchers have tried to assist golf swing by storing the energy of the X-factor stretch (Macadam et al. (2019); Park et al. (2012)). However, in these cases, the underlying assistance mechanism is unclear. This study investigates whether a passive elastic exoband can enhance clubhead velocity by changing the stretch’s timing and magnitude. We aimed to understand the interaction between the exoband, the X-factor, and other biomechanical factors and examined its potential to unlock new performance levels. This research paves the way for innovative exosuit designs that empower golfers to swing with higher velocities by harnessing the X-factor’s elastic potential.

METHODS: Two right-handed professional golfers participated in this study (sub01: female, age: 24 years, height: 1.6 m, weight: 74.21 kg; sub02: male, age: 22 years, height: 1.8 m, weight: 76.96 kg). A 12-camera OptiTrack motion capture system (250 Hz) recorded 3D trajectories of 57 reflective markers (46 on the golfer’s body, 6 on the exoband, 4 on the Iron7 club, and 1 on the ball). Two Kistler force plates (1000 Hz) measured ground reaction forces. Additionally, force in the exoband was measured with a Futek load cell (1000 Hz).

In this study, we utilized a simple elastic exoband that connects the shoulder to the pelvis by passing around the trunk to assist swing performance by storing tension and releasing it at the proper timing (Fig.1). We hypothesized that the application of this exoband could improve clubhead velocity. To identify the optimal location for the exoband, we considered four conditions, including the exoband pulling the left anterior shoulder towards the left PSIS (LF), left posterior shoulder to the left ASIS (LB), right anterior shoulder to the right PSIS (RF), and right posterior shoulder to the left ASIS (RB) (Fig. 2, right). For the testing session, following a warm-up and 5 swings without wearing the exoband, golfers performed 5 swings of each condition into a target net five meters away in a randomized order.

The swing with maximum clubhead velocity at impact for each condition was analyzed, starting from the beginning of the backswing and ending when the club reached an overhead horizontal position during the follow-through. We performed calculations using the AnyBody Modelling System (version 7.4.3) with a full-body musculoskeletal model from the AnyBody Managed Model Repository (AMMR) (Lund et al., 2023). The golf club, attached to both hands, was added as an object to the model with the same mass and inertial properties as the golfers' club. The exoband was defined using the AnyForce function and attached to the skeleton at both ends, with its position determined by six markers placed on the exoband. Tension in the exoband was considered using the loadcell data. For each participant, the skeleton was scaled before running the inverse dynamics. To account for the influence of the exoband, we ran the model twice: the first without the exoband to compute the overall joint power and the second with the exoband to determine the biological joint power. The difference between these values represents the exoband's contribution to power output. Then, the total mechanical work done by the golfer is determined by summing the integrated mechanical power graph of the lumbar and upper limb joints from the start of the downswing to the ball impact.

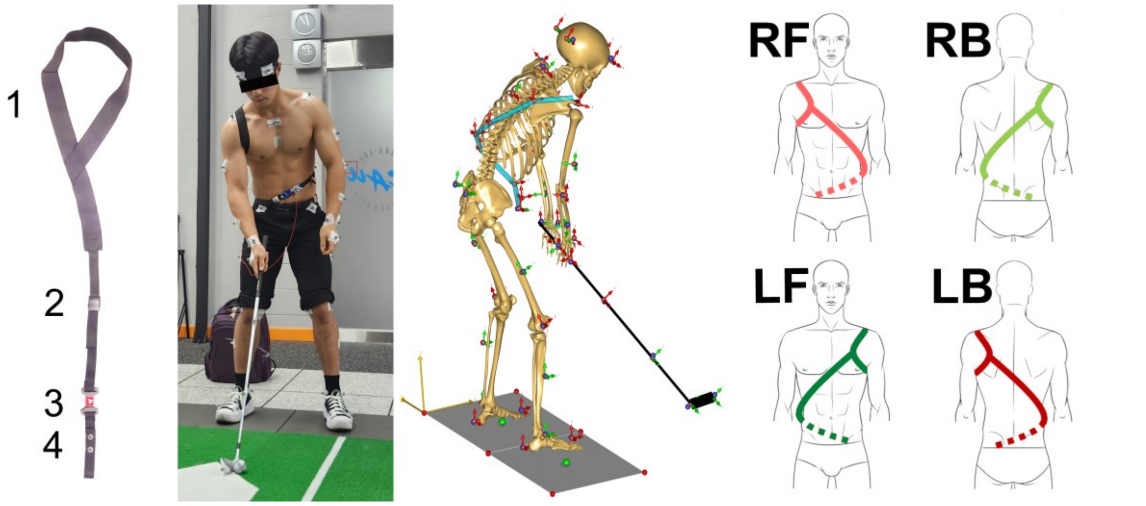

Figure 1: Left: Exoband (1. Elastic part, 2. Adjustable buckle, 3. Embedded loadcell, and 4. Lock buttons to attach the exoband to the belt). Middle: golfer while wearing the elastic exoband during RB condition and corresponding musculoskeletal model. Right: Exoband conditions.

RESULTS: The force in the exoband conditions is presented in Figure 2. Based on this graph, the LB condition provides the highest force for both subjects. Figure 3 shows the clubhead velocity at ball impact. Both subjects exhibited the highest velocity during the LB condition.

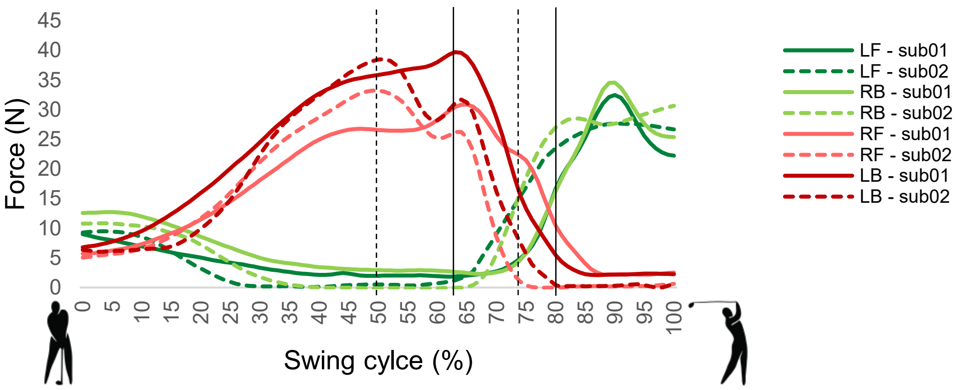

Figure 2: Exoband force for all conditions. The first and second vertical lines are the top of the backswing and ball impact, respectively.

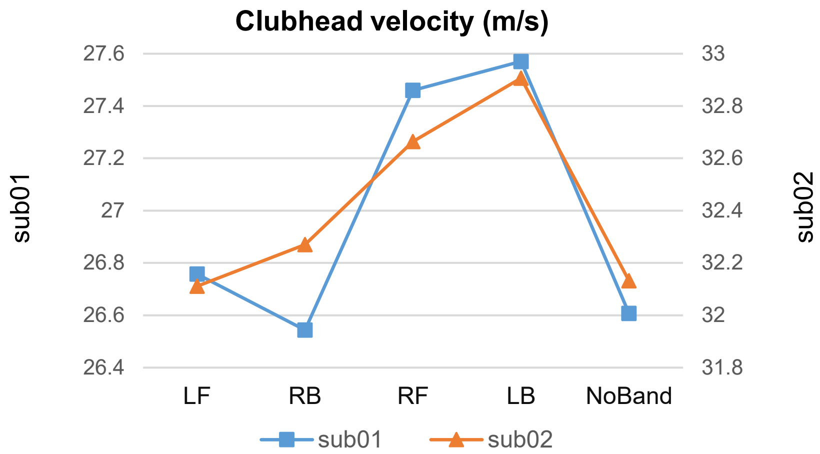

Figure 3: Clubhead velocity at the ball impact for all conditions.

Table 1 shows the X-factor, pelvic, and upper-torso axial rotation at the top of the backswing during all conditions. Based on the results, the RF and LB conditions exhibited a lower X-factor, attributed to decreased upper-torso rotation and increased pelvic rotation. Additionally, figure 4 illustrates the total work for all conditions. Notably, both subjects generated more work in the RF and LB conditions, with the LB condition showing the highest contribution from the exoband.

Table 1: X-factor, upper-torso axial rotation, and pelvic axial rotation for all conditions.

		Conditions				
Variables	**Subject**	LF	RB	RF	LB	NoBand
X-Factor (°)	sub01	44.79	46.07	38.39	33.95	43.39
	sub02	48.09	51.75	41.87	38.17	48.73
Upper-torso rotation (°)	sub01	-91.59	-92.79	-92.16	-89.29	-90.73
	sub02	-101.31	-101.11	-98.38	-96.73	-100.99
Pelvic rotation (°)	sub01	-46.80	-46.72	-53.78	-55.34	-47.34
	sub02	-53.22	-49.36	-56.51	-58.56	-52.27

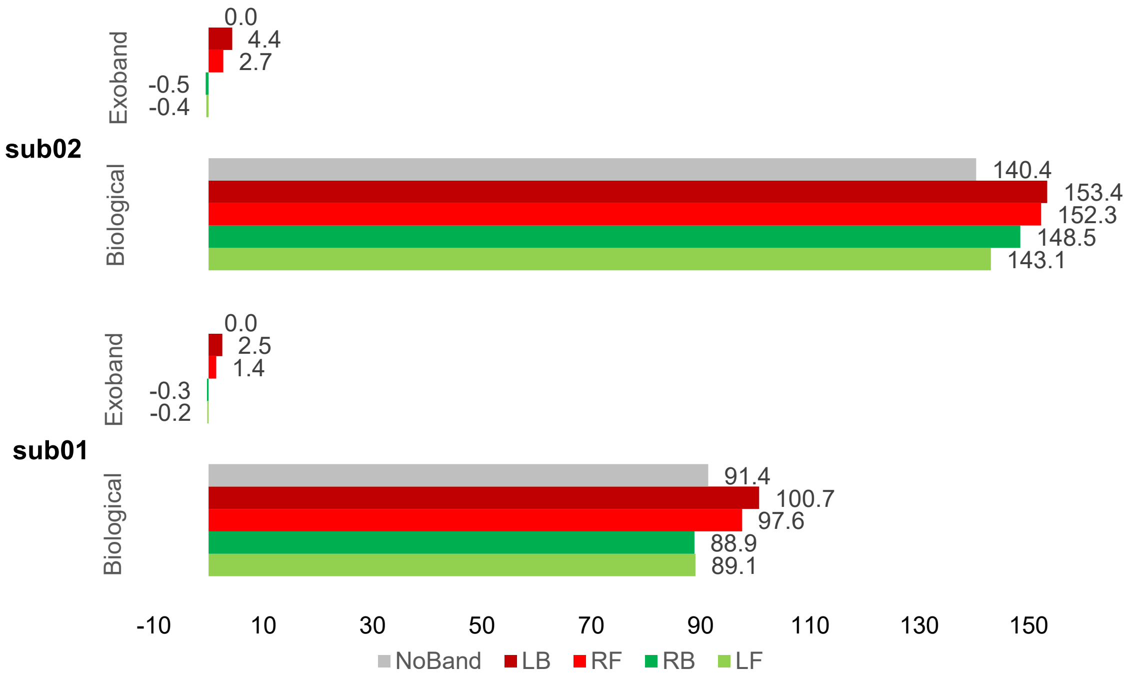

Figure 4: Total work (J) for biological joints and the exoband contribution.

DISCUSSION: Our findings underscore that the efficacy of a passive elastic exoband in enhancing clubhead velocity hinges on its placement and interaction with the golfer's biomechanics. The RF and LB configurations demonstrated the ability to store elastic energy during the backswing and release it during the downswing, generating a propulsive force that increased clubhead speed at impact. These configurations can, therefore, be categorized as accelerators. In contrast, the LF and RB configurations initiated energy storage before impact and continued accumulating it through the follow-through, acting as decelerators. These results emphasize the critical need to optimize exoband placement and timing to maximize its potential to enhance clubhead velocity in golfers.

Notably, the accelerator conditions (LB and RF) generally resulted in a lower X-factor than the decelerator (LF and RB) and the NoBand conditions. This finding can be explained by the pre-stretching effect of the exoband during the backswing. By assisting with pelvic rotation and limiting upper-body rotation, the accelerator exobands potentially reduce the need for a large X-factor at the top of the backswing. During the downswing, the stored elastic energy in the pre-stretched exoband can then be released more effectively, contributing to greater clubhead velocity despite a smaller X-factor. This finding aligns with previous research highlighting the importance of pelvic rotation and torso-pelvic separation in generating power during the golf swing (Cole & Grimshaw, 2009; Joyce, 2017).

The LB condition emerged as the most effective, leading to both the highest clubhead velocity and the greatest contribution from the exoband to overall work. This suggests that pulling the left posterior shoulder towards the left ASIS during the downswing optimizes the X-factor stretch stored in the passive elastic exoband, allowing golfers to convert stored elastic energy into explosive clubhead acceleration more effectively. A similar study by Park et al. (2012) showed that wearing a cloth with elastic elements that store the X-factor stretch during the backswing and releasing it during the downswing can significantly improve the ball speed and carry distance.

CONCLUSION: In summary, the outcomes of the present study propose that a simple passive elastic exoband designed to store the X-factor stretch can serve as an effective tool for enhancing clubhead velocity. The efficacy of the exoband lies in its ability to store elastic energy during the backswing and release it during the downswing, thereby augmenting the golfer's power output. Notably, the LB condition, involving the left posterior shoulder pulled towards the left ASIS, emerged as the most effective in increasing clubhead velocity and harnessing the exoband's contribution, suggesting the significance of precise exoband placement for maximizing its benefits. Future research endeavours can build upon these findings by exploring variations in exosuit designs, materials, and attachment points. This exploration aims to refine and optimize exosuit impact on golf swing performance, paving the way for continued advancements in golf biomechanics.

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