Influence of the projection plane and the markers choice on the X-factor computation of the golf swing X-factor: a case study

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1. Introduction

X-factor seeks to account for the dissociation between the shoulder and the pelvis girdles. It has been believed to be a key parameter for golf swing performance. However, several computational methods have been used and there is currently no consensus. Even if some comparison studies were performed, they remain incomplete.

Methodologies used for its computation are based on pelvic markers on the one hand, and either on acromions markers (Kwon et al. 2013) or thorax ones (Brown et al. 2013) on the other hand. These markers permit to define an upper and a lower lines. These lines are then projected either in the horizontal plane or in the swing plane. Then, this factor could be defined either as the angle at the beginning of the downswing phase (or top of the backswing), or as the maximal value of this separation angle. In the latter case, it is named the X-factor stretch (Cheetham et al. 2001).

The objective of this study was to evaluate if the methodological choice, *i.e.*, based on acromion versus thorax markers, and depending on the plane of projection, have a significant influence on both the X-factor and X-factor stretch estimations.

2. Methods

2.1. Subject

One professional male golfer was recruited for this experiment. He was informed and gave his written consent before the experiment. This protocol was approved by an independent ethics committee (2015-A01760-49, Ile de France X).

2.2. Acquisitions

The volunteer was equipped with 65 reflective markers with 4 additional markers for the golf club. Markers were tracked by a 12-cameras optoelectronic motion capture system (Vicon system, Oxford metrics, UK; 200 Hz). The volunteer performed a series of 10 swings with his own driver club. Swing performance was assessed with a dedicated ball flight radar (TrackMan 3, TrackMan, USA) by considering the club head speed at impact. The five best swings were retained and processed in this study.

2.3. Processing

The swing plane was computed based on the clubhead marker by computing the best fit plane with a root mean square criterion, during the last part of the downswing (Morrison et al. 2014).

Markers positions were used to animate a rigid bodies model (Bourgain et al. 2018), based on a multi-body kinematic optimization algorithm, on OpenSim software (Delp et al. 2007). Resulting markers were used to compute two computational methods used to define the X-factor:

- The upper body markers were either the thorax ones (7th cervical and manubrium) or both acromions.
- The plane of projection was either the horizontal plane (HP), or the functional swing plane (FSP).

An estimation of the shoulder/pelvis dissociation was performed based on markers of the acromions and pelvis. The thorax/pelvis based on the markers of the thorax and pelvis. For each method, the X-factor (XF) was defined as the angle at the top of backswing and the X-factor stretch (XFS) was defined as the maximum angle.

The correlation between each computed X-factor and the performance was estimated by computing the linear correlation coefficient (R).

3. Results and discussion

The clubhead speed at impact varied from 45.1 to 46.3 m/s. As it could have been expected, both

Table 1. values in degrees of XF, XFS according to the methodology chosen. S/P: shoulder/pelvis dissociation method, T/P: thorax/pelvis method.

	Horizontal plane		Swing plane	
XF(°)	S/P	T/P	S/P	T/P
Mean (SD)	56,5 (1,4)	37,8 (0.9)	50,2 (1.8)	36,4 (1.0)
Range	55.3	37.3	47.9	35.3
	58.6	39.4	52.3	38.1
Correlation (R)	0.86	0.98	0.74	0.94
XFS(°)	S/P	T/P	S/P	T/P
Mean (SD)	56.7 (1.2)	38.0 (0.8)	54.4 (0.9)	38.8 (0.6)
Range	55.8	37.5	53.6	37.9
	58.6	39.5	55.6	39.6
Correlation (R)	0.87	0.96	0.50	0.81

X-factor and X-factor stretch were higher for shoulder/pelvis dissociation than for thorax/pelvis dissociation, with an overall average difference of 19° and 14° for horizontal and swing planes projection, respectively. This indicates that the shoulder complex contributed noticeably to the XF, which is in accordance with a previous study (Bourgain et al. 2018). Values of XF and XFS with the different methods, and their linear correlation with clubhead speed, were reported in Table 1.

Values of XF and XFS in the thorax/pelvis method were in accordance but slightly higher of previously reported results (Brown et al. 2013). As they considered elite amateurs and not professionals, this is in accordance with the idea of increasing the XF and XFS with golfer skills. Values of XF and XFS in the shoulder/pelvis method were in accordance with a previous study (Kwon et al. 2013).

It can also be noticed that the consistency of those angles, *i.e.*, the standard deviation, is less than 2°, which represent less than 3% of the nominal value. The influence of the chosen plane for the projection depends on the methodology: with the thorax/pelvis method the mean value variated of 2 and 4% for XFS and XF respectively, whereas, for shoulder/pelvis methods it was 4 and 11% for XFS and XF respectively.

According to the linear coefficient of correlation, this subject appeared to have a better performance when he increased his thorax/pelvis dissociation.

However, this is only a case study, and those tendencies should be confirmed on more subjects.

4. Conclusions

The method chosen for computing the X-factor highly influences its value and its correlation to performance. The main element influencing its computation is the upper anatomical region taken into account. The plane chosen for the projection had a limited influence. The authors recommend to explicitly indicate the methodology used for X-factor computation, in particular the markers used, the plane of projection and the instant of computation to help comparison between studies.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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