Changes of Impact Force During Performance of Straight Punch With Two Boxing Techniques – Case Study

Vedran Dukarić, Mateja Očić, Ivan Bon, Tomislav Rupčić, Damir Knjaz

Laboratory for Sports Games, Faculty of Kinesiology, University of Zagreb, Zagreb, Croatia

ABSTRACT

PURPOSE: Performance in boxing is a combination of strength, speed, and stability to create maximum impact. One of the types of punches commonly used in boxing is the straight punch. The magnitude of force exerted at the point of impact is influenced by a number of factors. Therefore, some biomechanical parameters can have greater effect than others during punch performance. Likewise, different technique modalities influence punch force. This study aims to determine differences between kinetic and kinematic parameters of punches performed with two different techniques (with and without weight shifting). METHODS: Overall, 20 straight punches were performed (10 for each observed technique) by a top-level female boxer (26.1 years old, height 170.3 cm, weight 63.2 kg). Afterwards, four kinematic variables (shoulder, upper arm, forearm, and hand velocities) were analyzed together with the position of center of mass (Xsens, Awinda). Also, overall foot pressure force of both feet (Novel pressure insoles) was analyzed for each technique, as well as the impact force of each punch (Punchsensor). Differences between the techniques were determined by MANOVA. RESULTS: Significant differences were found in foot pressure force and impact force, with higher values of punch force determined in the straight punch performance that includes weight shifting (p=0.00). Regarding kinematic parameters, there were significant differences in shoulder velocity, forearm velocity, and center of mass position (p=0.00). Upper arm and hand velocity variables did not differ significantly. This result indicates that different punch preparation can exhibit greater force and better performance. CONCLUSION: The understanding of movement pattern in punching could provide insightful instruction to coaches and boxers on how to generate powerful straight punches. The presented data objectively determined differences between two approaches in performing a straight punch which could help in correcting technical performance.

INTRODUCTION

Boxing is a combat sport that has high physical and mental demands with the primary objective to perform as many punches as possible and to avoid getting hit back (Šiška, Brodani, Štefanovsky & Todorov, 2016). There are four main types of punches in boxing, and those are the jab – a sudden punch, the cross – a straight punch, the hook - a short side power punch and the uppercut – a short swinging upward power punch (Khasanshin, 2021). A straight right punch is thrown often by the dominant hand and its technique is very precise and could potentially alter the competition result. The magnitude of force exerted at the point of impact is governed by a number of factors, such as the kinematic parameters of upper limbs, trunk movements, leg movements, and weight shifting (Cheraghi, Alinejad, Arshi & Shirzad, 2014). Performance in boxing would then be a combination of strength, speed, and stability to create maximum impact (Loturco et al., 2016). In terms of kinematic analysis, researchers used the accelerometer and motion analysis to analyze punching velocity, as well as linear velocities of the fist, elbow, and shoulder. The upper extremity was preferred to the lower extremity because the lower extremity was relatively static compared to the upper extremity (Tong-Iam, Rachanavy & Lawsirirat, 2017). The efficiency of a punch in boxing largely depends on the dynamics of velocity of body segments carrying out movements in multi-link systems of the human body (Gu, Popik & Dobrovolskiy, 2018). Based on the above mentioned, it is also required to engage a muscle chain as much as possible in order to have a strong punch. One such example would be twisting the torso in the direction of the punch, so not only the mass of the hand and arm are involved (Deliu, Stoica & Dreve, 2021). Although lower body segments do not engage directly in the punch, they are of great importance for a quick reaction and a stable position. Leg drive has been observed to build-up momentum in the kinematic chain helping towards a greater fist velocity and the effective mass shifting. Also, stability and shifting weight on both legs with pressure distributed optimally on different parts of the foot in crucial moments could help in performing a punch of great impact (El-Oujaji, Provot, Bourgain & Dinu, 2019). Force impact is mainly produced by body segment mass and velocity. Velocity depends on the rational mechanical structure of a punching movement and is ensured by consistent work of the body segments, which are displayed in a strict sequence (Gamaliy & Vasilyev, 2004). The biomechanical analysis of straight punches performed with two different preparatory techniques in the first phase of landing a punch will enable us to identify the kinematical features of punch effectiveness and to compare differences between these two approaches in performing a straight punch in boxing. The understanding of movement pattern in punching could provide insightful instruction for coaches and boxers on how to generate powerful straight punches.

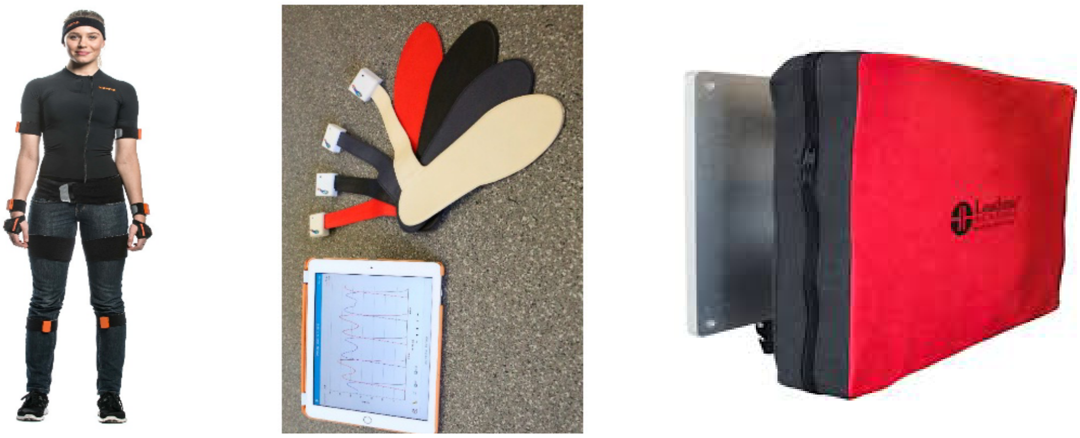
METHODS

Participant

The respondent was a top-level Croatian female boxer in the category up to 64 kg (26.1 yr; 170.3 cm; 63.2 kg). During the testing, the respondent was in the preparatory period, without health problems or any locomotor difficulties. Only punches with the dominant (right) hand were observed and analyzed.

Variables

For the purpose of testing, the following measuring devices were used: Punchsensor (Loadstar sensors, USA) for measuring impact force; Loadsol (Novel, Germany) kinetic insoles for measuring pressure force or force transfer; Xsens (Awinda, The Netherlands) kinematic system for measuring space-time parameters of the upper extremities.



a) **b)** **c)**

Figure 1. Kinetic and kinematic systems used in the measurements: **(a)** – Xsens Awinda kinematic suit; **(b)** – Novel Loadsol insoles; **(c)** - Punchsensor force sensor.

The following variables were observed by using the kinematic suit: maximum velocity of the right shoulder when performing a punch (Shoulder_V); maximum velocity of the upper arm when performing a punch (Upper_arm_V); maximum velocity of the forearm when performing a punch (Forearm_V); maximum velocity of the hand when performing a punch (Hand_V); the lowest position of the body's center of mass (COM). Precise measurement with the kinematic suit has been observed in studies (Dinu et al., 2016; Khurelbaatar, Kim, Lee & Kim, 2015) and it represents an ideal instrument for observing boxing performance technique. The maximum pressure forces of the left (Foot_L_F) and right (Foot_R_F) foot when performing a punch were observed with pressure force measuring insoles. Studies (Burns, Zendler & Zernicke, 2019; Renner, Williams & Queen, 2019; Seiberl, Jensen, Merker, Leitel & Schwirtz, 2018) previously established good metric characteristics of this device. The Punchsensor measured the maximum force of a single punch (Punch_F). The measuring systems were used synchronously, i.e., the kinematic parameters of performance technique and the kinetic parameters of foot pressure force and punch force were recorded at the same time. The device synchronization was conducted similarly as in previous studies (Bon, Očić, Cigrovski, Rupčić & Knjaz, 2021; Čubrić, Rupčić, Cigrovski, Matković & Šagat, 2021).

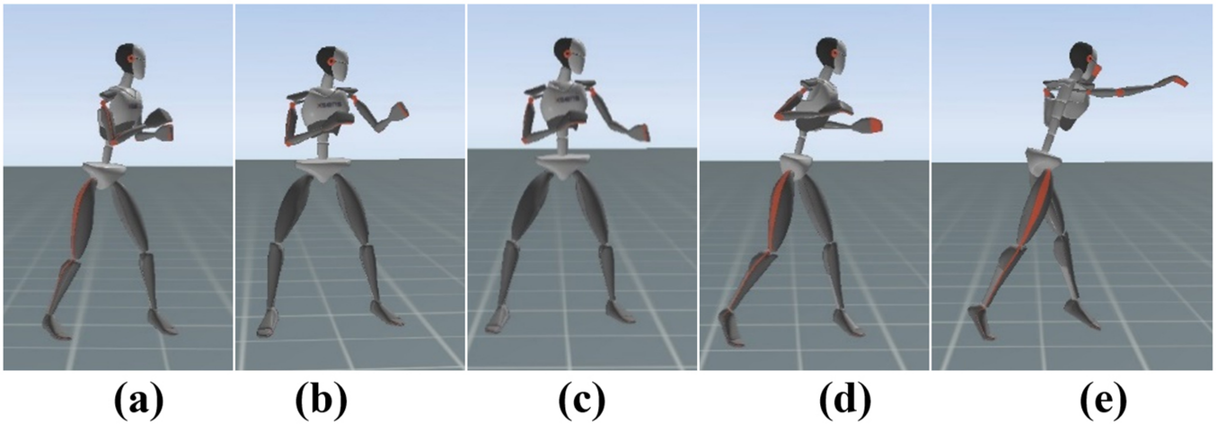


Figure 2. Performance of the straight punch without weight shifting: **(a)** – starting position; **(b)** – initial swing phase; **(c)** – initial punch phase; **(d)** – middle punch phase; **(e)** – end of the straight punch.

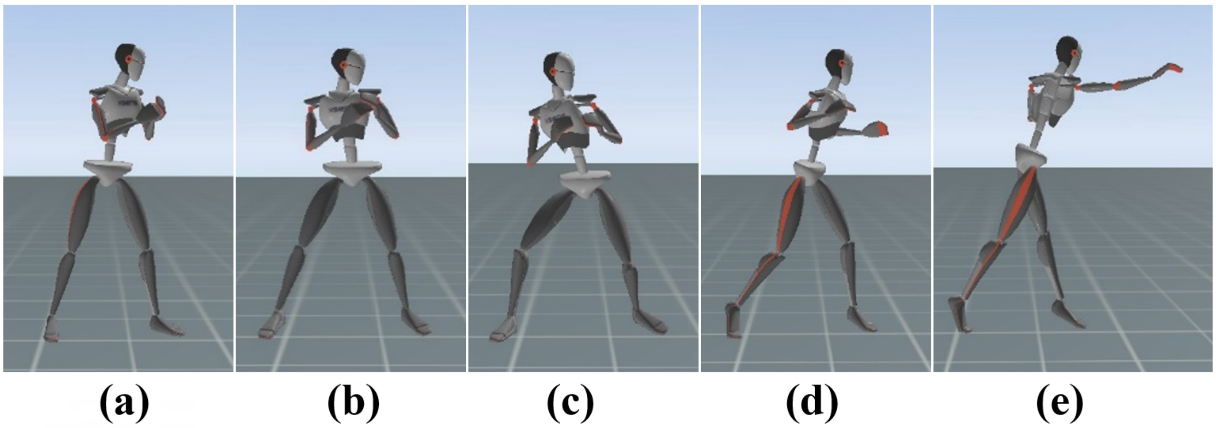


Figure 3. Performance of the straight punch with weight shifting: **(a)** – starting position; **(b)** – initial swing phase; **(c)** – initial punch phase; **(d)** – middle punch phase; **(e)** – end of the straight punch.

Statistical analysis

Statistical package Statistica version 13.5.0.17 (TIBCO Software Inc, Palo Alto, CA) was used for data analysis. Basic descriptive parameters for all measured variables were calculated. MANOVA was used for the detection of differences between straight punch performance when using two different preparatory techniques for the punch (with and without weight shifting). Differences between observed parameters were determined by using ANOVA analysis. The results were considered significant when $p < 0.05$.

RESULTS AND DISCUSSION

Table 1. Basic descriptive statistical parameters of the observed variables for both preparatory techniques of performing the straight punch.

		N	Mean	Minimum	Maximum	St.Dev.
Foot_L_F (N)	Non-shift	10	1087,35	794,88	1415,10	220,20
	Shift	10	790,82	657,80	933,16	84,91
Foot_R_F (N)	Non-shift	10	1275,71	956,12	1844,70	277,82
	Shift	10	1490,23	1426,04	1574,80	50,13
Shoulder_V (m/s)	Non-shift	10	1,81	1,69	1,98	0,10
	Shift	10	2,06	1,92	2,25	0,13
Upper_arm_V (m/s)	Non-shift	10	3,27	2,45	3,91	0,41
	Shift	10	3,51	2,71	4,07	0,43
Forearm_V (m/s)	Non-shift	10	8,63	8,30	9,12	0,27
	Shift	10	9,34	8,57	9,93	0,45
Hand_V (m/s)	Non-shift	10	8,71	7,24	9,70	0,96
	Shift	10	9,29	7,43	10,46	0,99
COM (cm)	Non-shift	10	88,74	87,58	91,09	1,11
	Shift	10	82,41	81,31	85,14	1,08
Punch_F (N)	Non-shift	10	1396,40	1198,00	1500,00	96,51
	Shift	10	2091,20	1973,00	2253,00	80,55

Legend: Foot_L_F – pressure force of the left foot; Foot_R_F – pressure force of the right foot; Shoulder_V – velocity of the shoulder joint; Upper_arm_V – velocity of the upper arm segment; Forearm_V – velocity of the forearm segment; Hand_V – velocity of the hand segment; COM – center of mass position in centimeters; Punch_F – value of force exerted during straight punch.

The basic descriptive indicators of the results indicate higher values of foot pressure forces on the ground in conditions when the punch was preceded by the transfer of body mass to the back leg. The highest achieved pressure force was in the right foot (1844.70 N). Also, when observing the velocities of individual segments of the hand used to perform the punch, higher maximum velocities were achieved when the mass was transferred. The more distal the segment, the higher was the velocity achieved. The wrist velocity was the highest (10.46 m/s). COM values were higher in conditions when no additional preparation for the punch was carried out. Punch force (Punch_F) was higher with previous preparation (2091.20 vs. 1396.40 N).

Table 2. Results of MANOVA for the straight punch executed with two different preparatory techniques.

Test	Value	F	P
Wilks	0,02	66,37	0,00*

*marked values were significant when $p < 0.05$

Results presented in Table 2 show statistically significant difference between two observed preparatory techniques (with and without weight shifting) of straight punch performance (F=66,37; p=0,00).

Table 3. Results of ANOVA analysis of differences between observed parameters.

Dependent Variable	F	p
Foot_L_F	15,79*	0,00*
Foot_R_F	5,77*	0,03*
Shoulder_V	22,88*	0,00*
Upper_arm_V	1,60	0,22
Forearm_V	18,20*	0,00*
Hand_V	1,72	0,21
COM	165,76*	0,00*
Punch_F	305,50*	0,00*

Legend: *marked values were significant when $p < 0.05$; Foot_L_F – pressure force of the left foot; Foot_R_F – pressure force of the right foot; Shoulder_V – velocity of the shoulder joint; Upper_arm_V – velocity of the upper arm segment; Forearm_V – velocity of the forearm segment; Hand_V – velocity of the hand segment; COM – center of mass position in centimeters; Punch_F – value of force exerted during straight punch.

Table 3 shows differences in the observed kinetic variable of the left foot pressure force between two preparatory techniques for straight punch performance ($p < 0.00$). Also, the difference was confirmed when observing pressure force of the right foot ($p = 0.03$). When analyzing kinematic parameters, there were differences in shoulder velocity when performing the straight punch ($p < 0.00$). Also, forearm velocity differed significantly between the performed preparatory techniques ($p < 0.00$). The mentioned velocity values were significantly higher when shifting the weight before the straight punch performance. Significant difference was also found in the values of center of mass ($p < 0.00$), i.e., based on the results of descriptive statistics, the boxer was in lower position when shifting her weight on her back foot before the straight punch performance. When observing overall values of impact force of the straight punch, it can be concluded that there was significant difference between two preparatory techniques ($p < 0.00$). When performing weight shifting before the punch, a greater force of impact was exerted. Based on the gained results, it can be concluded that the boxer was more successful when performing weight shifting on her back foot in the first phase of performing the straight punch. In that case, higher velocity values were achieved in the shoulder and forearm. Also, the boxer starts the punch in lower position, which, in combination with the above mentioned, consequently helps in producing greater impact force of straight punches. The exerted force was much higher when compared to the technique that does not include weight shifting (2091.20 N vs. 1396.40 N). Šiška et al. (2016) determined average values of senior boxers (3585.9 ± 1366.2 N) for both genders. As this was almost double than in the presented research, Šiška et al. did not separate male from female boxers so it cannot be completely compared to the results of this study. Comparing different force strikes in combat sports, authors Beranek, Votapek & Stastny (2020) emphasized that the straight punch exerted the greatest values of 3427 N. These forces are under great influence of body weight and length of body segments. Further investigation and detailed analysis of kinematic parameters are needed to fully understand the significance of the straight punch and the factors influencing its ideal performance. Also, it has to be mentioned that the pressure force of the back foot was higher when shifting the weight (1490,23 N vs. 1275,71 N), which can also help in greater energy creation and in energy transfer necessary for a greater impact. It should be noticed that, when discussing factors that influence the punch outcome, some authors conclude that optimal values of kinematic parameters are important for the performance of the punch. However, even more important are inter- and intra-muscular coordination which directly influence the force developed in a strike (Băiţel & Deliu, 2014). The above mentioned is the greatest limitation of this study because detailed information about muscle activity could help in fully understanding the movement pattern of the executed straight punches.

CONCLUSION

Based on the conducted analysis for the purpose of this case study, it can be concluded that greater impact forces are achieved when using preparatory technique which includes weight shifting on the back foot in the first phase of executing a straight punch. Higher values of shoulder and forearm velocities were determined, along with lower position of center of mass and higher values of foot pressure force of the back foot. These are the factors that help in transferring more energy to the straight punch. However, to make valid conclusions, the overall biomechanical analysis should be conducted to get a clearer insight in various integrated parts of kinematics, kinetics and muscular involvement when executing different boxing techniques and punches. Also, it is important to conduct the same testing protocol with a larger sample size and to compare the observed parameters for various categories, and for both males and females. Nevertheless, the data presented in this research can serve to coaches in the overall analysis of the boxing technique. Even though the observed variables represent a small detail in the straight punch performance, it is the little details that often make the difference between winning and losing.

REFERENCES

Băiţel, I. & Deliu, D. (2014). Kinematic Analysis of the Cross Punch Applied in theFull-contact System Using Inertial Navigation Technology and Surface Electromyography. *Procedia - Social and Behavioral Sciences*, 117, 335–340.

Bon, I., Očić, M., Cigrovski, V., Rupčić, T., Knjaz, D. (2021). What Are Kinematic and Kinetic Differences between Short and Parallel Turn in Alpine Skiing? *International Journal of Environmental Research and Public Health*, 18(6):3029.

Beránek, V., Votápek, P. & Stastny, P. (2020). Force and velocity of impact during upper limb strikes in combat sports: a systematic review and meta-analysis. *Sports biomechanics*, 17, 1–19.

Burns, G.T, Deneweth Zendler, J. & Zernicke, R.F. (2019). Validation of a wireless shoe insole for ground reaction force measurement. *Journal of Sports Sciences*, 37(10), 1129-1138.

Cheraghi, M., Alinejad, H.A., Arshi, A.R. & Shirzad, E. (2014). Kinematics of Straight Right Punch in Boxing. *Annals of Applied Sport Science*, 2(2), 39–50.

Čubrić, S., Rupčić, T., Cigrovski, V., Matković, B., Šagat, P. (2021). Relationship between pressure force and some kinematic parameters when performing jump shot in basketball. *9th International Scientific Conference on Kinesiology*, 2021, Opatija, Croatia, 107–111.

Deliu, R., Stoica, M. & Dreve, A. A. (2021). Possibilities Of Complex Objectivation Of Technical Elements Combination From Martial Arts With The Help Of Mvn Xsens. Bucharest: "Carol I" National Defence University.

Dinu , D., Fayolas, M., Jacquet, M., Leguy, E., Slavinski, J. & Houel, N. (2016). Accuracy of postural human-motion tracking using miniature inertial sensors. 11th conference of the International Sports Engineering Association, ISEA 2016.

El-Oujaji, S.T., Bourgain, P.M. & Dinu, D. (2019). Difference of stability between two elite boxing groups: a preliminary study. *Computer Methods in Biomechanics and Biomedical Engineering*, 22(1), 481–483.

Gamaliy, V. & Vasilyev, V. (2004). Biomechanical features of hit attacks technique of athletes with different qualification in martial arts. *International Journal of Biomedical Engineering and Technology,* 28(4), 114–122.

Gu, Y., Popik, S. & Dobrovolskiy, S. (2018). Hand punch movement kinematics of boxers with different qualification levels. *International Journal of Biomedical Engineering and Technology*, 28(4), 366–376.

Khasanshin, I. (2021). Application of an Artificial Neural Network to Automate the Measurement of Kinematic Characteristics of Punches in Boxing. *Applied Sciences*, 11, 1223.

Khurelbaatar, T., Kim, K., Lee, S. & Kim, Y.H. (2015). Consistent accuracy in whole-body joint kinetics during gait using wearable inertial motion sensors and in-shoe pressure sensors. *Gait & Posture*, 42 (1), 65–69.

Loturco, I., Nakamura, F.Y., Artioli, G.G., Kobal, R., Kitamura, K., Cal Abad, C.C., Cruz, I.F., Romano, F., Pereira, L.A. & Franchini, E. (2016). Strength and power qualities are highly associated with punching impact in elite amateur boxers. *Journal of Strength and Conditioning Research*, 30(1), 109–116.

Renner, K., Williams, D. & Queen, R. (2019). The Reliability and Validity of the Loadsol® under Various Walking and Running Conditions. *Sensors*, 19(2), 265.

Seiberl, W., Jensen, E., Merker, J., Leitel, M. & Schwirtz, A. (2018). Accuracy and precision of loadsol® insole force-sensors for the quantification of ground reaction force-based biomechanical running parameters. *European Journal of Sport Science*, 18(8), 1100–1109.

Šiška, L., Brodani, J., Štefanovsky, M. & Todorov, S. (2016). Basic reliability of a boxing punch. *Journal of Physical Education and Sport,* 16 (1), 241-244.

Tong-Iam, R., Rachanavy, P. & Lawsirirat, C. (2017). Kinematic and kinetic analysis of throwing a straight punch: the role of trunk rotation in delivering a powerful straight punch. *Journal of Physical Education and Sport*, 17(4), 2538–2543.