7．腓腹筋の筋力ポテンシャルからみた大外刈の刈り脚関節角度の影響

カリフォルニア州立大学サクラメント校　今村　ロドニー
早稲田大学スポーツ科学学術院　射手矢　岬
カリフォルニア州立大学サクラメント校　ダリル　パーカー

7．The Influence of Joint Positioning of the Osoto-gari Sweeping Leg on Muscle Force Potential of the Gastrocnemius

Rodney T. IMAMURA　(California State University Sacramento)
Misaki ITEYA　(Waseda University Faculty of Sport Sciences)
Daryl L. PARKER　(California State University Sacramento)

要　旨

大外刈の刈り脚は，農家の刃物や鎌を用いる時の「刈る」という動作で表され，その名の通り「大きく外から刈る」と名付けられている．バイオメカニクスの観点から刈り脚の形状は，足首，膝，および股関節の関節角度によって規定される．刈り脚が生み出す力は筋の長さや関節角度によって大きく影響を受けるため，刈り脚の形状からその効果は予測できる．

そこで，本研究の目的は刈り脚の足関節および膝関節角度を測定し、刈り脚の関節角度から膝の屈曲および足首の底屈筋である腓腹筋の筋長を推測し，刈り足の力発揮との関係を調べることであった．

被験者は36人（有段者18人，初心者18人）で，大外刈時の刈り脚を矢状面からカシオ社製カメラを用い240 Hzで撮影した．施技は受を仮想した棒を用いて行った．従って，発生する筋力は取自身の自重のみが負荷となった．足首と膝の関節角度の測定は刈り脚が棒に接触した時点とした．角度の値が大きくなれば，足首の背屈および膝の伸展を表すようにした．

有段者群と初心者群の比較のためt検定を行ったところ，足関節角度において１％で有意差を認めたが，膝関節角度において有意差は認められなかった．先行研究と同様に，結果は有段者群においてより大きな足関節底屈を示し，経験者では初心者よりも足関節底屈筋が使用されるという知見を実証した．しかし，有段者群の足関節と膝関節の形状は腓腹筋が短縮されており，大きな力発揮をするというよりは，むしろより小さな力発揮の可能性を示した．

結論として，なぜ有段者群は大外刈の刈り動作中に足関節底屈を好むのか，未だ多くの疑問が残る．しかし，興味深いことに，有段者群の足首および膝関節の形状は，湾曲した刃物（鎌）と

似ており「大きく外から刈る」という名前と合致する.

Introduction

Osoto-gari means major outer leg reap, with the word “reap” defined as a cutting motion by way of harvesting crops with a sickle. From this perspective, the characteristics of the *osoto-gari's* sweeping leg can be likened to a sickle cutting through an opponent's leg. From a biomechanics perspective, the sweeping leg's force is generated by muscle contractions, which in turn create angular movements about joints. Specifically, hip extensor muscles generate force to extend the hip, knee flexor muscles to flex the knee, and ankle plantarflexors to plantarflex the ankle during the downward motion of the sweep.

Research has verified the actions of the sweeping leg, with hip extension and knee flexion common to all judoka (Imamura and Johnson, 2003; Narazaki et al. 2007; Imamura et al. 2011). The action of the ankle, however, has been found to vary and may be related to skill level. Research has shown less plantarflexion velocity for novice judoka compared to black belt judoka (Imamura and Johnson, 2003). The study also indicated that ankle activity might be related to a skill pattern called the kinetic chain, where proximal joint momentum is transferred to distal joint momentum in a chained pattern. In this regard, black belt judoka were thought to maximize their plantarflexion momentum using timing and skill.

However, recent studies have suggested that chained motions may not be used during the *osoto-gari* downward sweep. Imamura et al. (2011) measured peak power for hip, knee, and ankle and found little indication of a chained pattern for black belt judoka. Narazaki et al. (2007) measured angular displacements of the same joints. Their study found a synchronized occurrence of joint motions rather than a chained pattern. In addition, the *osoto-gari* sweep is not typical for motions that benefit form a kinetic chain. Motions that require the distal segments to be the fastest part of the body, such as over-hand throwing, greatly benefit from a chained motion. However, unlike the throwing motion, *osoto-gari's* action point, or contact point, is not at the ankle, rather, it is near the knee. From this perspective, plantarflexion activity should not be considered to have a major contribution to *osoto-gari* sweep effectiveness, particularly if the contact point of the sweeping leg and opponent is the focus.

Still yet, joint positioning in itself can have an effect on muscle force production. It is commonly known that joint positions can influence muscle length and, in turn, affect the muscle's ability to forcefully contract. Furthermore, muscles that crossover more than one joint can be influenced by joint positioning at two or more joints, commonly referred to as active insufficiency (Crawford and James, 1980). The gastrocnemius is of particular interest in terms of *osoto-gari*, because it is a major contributor to forceful knee flexion and ankle plantarflexion. Likewise, its ability to produce force can be influenced by the positioning of both the knee and ankle joints.

Up to now, the particulars of the *osoto-gari* sweep biomechanics are not fully comprehended. Plantarflexion activity has been consistently shown to be active for high level judoka. Yet, its contribution to sweeping leg power and overall performance is unclear. Therefore, it was the purpose of this study to further investigate ankle plantarflexion and its significance to the downward sweeping power of *osoto-gari*. Specifically, joint positions of the ankle and knee will be measured to investigate muscle length and force potential of the gastrocnemius muscle.

Methods

A total of 36 subjects (18 black belt; 18 white belt) were used for this study. Black belt subjects consisted of 14 males and 4 females ranging in skill level from shodan to rokudan. The novice subjects (7 female; 11 male) were all white belt level with at least 12 weeks of judo instruction and training. Subjects were filmed in the sagittal view using a single high-speed video camera (Casio; 240 Hz).

Subjects performed the *osoto-gari* throw without uke, using a stick for balance (Figure 1). Since the stick apparatus was unfamiliar to each subject, they were allowed to practice until they felt comfortable. The subjects were instructed to use maximal speed without losing their footage. In this respect, maximal speeds were encouraged without losing the mechanics of a clean *osoto-gari* throw. Furthermore, the sweeps were considered "ghost" sweeps, since the subjects were instructed to avoid contact with the stick. For convenience, the subjects were provided a target for sweep contact. This was done by hanging a belt from the top of the stick. In this regard, the belt provided a target but did not introduce any significant resistance to the sweeping leg.

Joint angles of the knee and ankle were measured using a motion analysis software (Dartfish

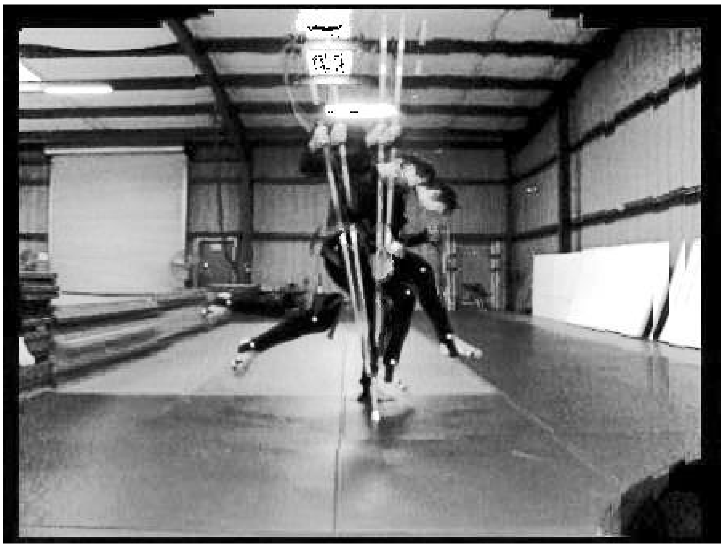

Figure 1. Multi-frame illustration of the Osoto-gari downward sweeping motion using the stick and belt apparatus.

Pro-Suite; Switzerland). The single time frame used for measurement was considered the perceived contact point with uke's leg, which was estimated by the contact with the hanging belt. Angles were measured such that larger angles corresponded with greater knee extension and greater ankle dorsiflexion (Figure 2). Each subject provided three sweeping trials. Trial averages were determined for each subject and sample averages were determined for each group. Independent samples t-test (α = .05) was used to compare differences in joint angles between groups.

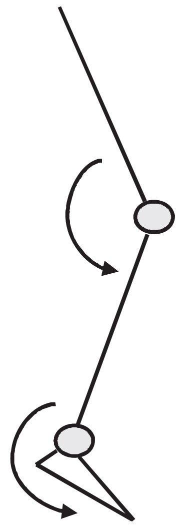

Figure 2. Angles were measured such that larger angles were associated with greater knee extension and ankle dorsiflexion.

Results

There was a significant difference (p = 0.000) between ankle joint position between black belt and novice judoka. The average ankle angles were 216.28 (± 12.27) degrees and 239.10 (± 13.77) degrees for black belt and novice judoka, respectively. This was a predicted outcome since experienced judoka have shown consistent ankle plantarflexion activity in the past. For the knee, there was no significant differences (p = 0.238) found between groups. The average knee angles were 131.36 degrees (±23.88) and 136 degrees (±13.28) for black belt and novice, respectively. Although black belt judoka experienced greater knee flexion overall, there was not a significant difference between novice judoka. In fact, black belt judoka were found to vary their knee angles (±23.88) much more than novice (±13.28). The results are illustrated in Figures 3 and 4.

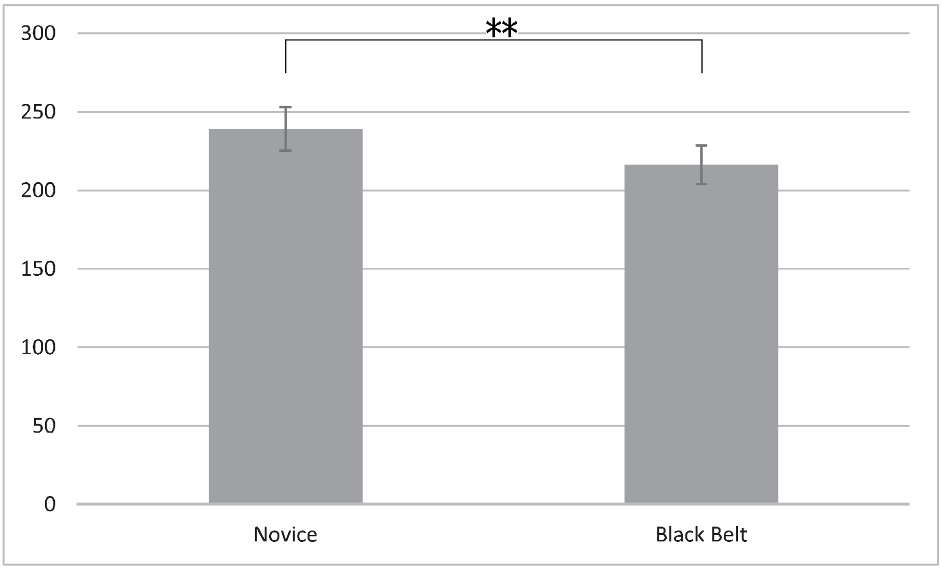

Figure 3. The results indicated a significant difference (**p< 0.01) between white belt and black belt subjects for ankle angle (Degrees).

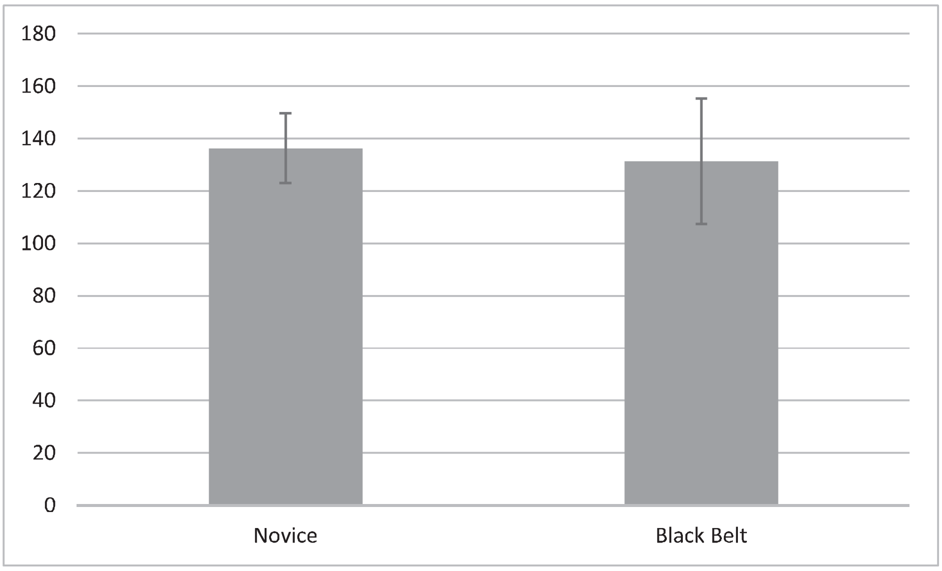

Figure 4. The results indicated no significant difference (p = 0.238) between white belt and black belt subjects for knee angle (Degrees).

Discussion

The results of the study indicate that experienced judoka prefer to position their ankle in plantarflexion rather than dorsiflexion, during the downward motion of the *osoto-gari* sweep. This is consistent with previous research that found vigorous plantarflexion activity with experienced judoka (Imamura and Johnson, 2003; Narazaki et al. 2007; Imamura et al. 2011). In terms of gastrocnemius muscle length and force production, the results indicate that black belt judoka do not position their joints in a position for optimal force production. According to concepts established by Crawford and James (1980), the gastrocnemius should create the greatest amount of force during a neutral muscle "resting" length. That said, a plantarflexed position of the ankle will create a shortening of the muscle and, therefore, warrant a lengthening response at the knee (i.e. knee extension). This was not demonstrated in this study. While not significantly different from novice, black belt subjects actually depicted greater knee flexion angles. Thus, black belt judoka under these conditions are actually at a disadvantage in terms of potential gastrocnemius muscle force production.

It should be mentioned, however, that knee flexion is not dictated by the gastrocnemius alone. The hamstring muscles are a major contributor to knee flexion and, for the same reasons above, can be influenced by joint positioning of the knee and hip. Although not measured in this study, hip angles can influence muscle length and hamstring muscle force production. According to Imamura and Johnson (2003), black belt judoka also demonstrated significantly larger trunk flexion velocity during the downward sweep. Because of the large trunk flexion activity and perceived greater flexion, it is possible that black belts will increase knee flexion to avoid overstretching the hamstring muscle in this case. This may explain why knee flexion was more prominent among black belt subjects. Depending on the degree of trunk flexion between subjects, it may also explain the large variability in this measurement.

Clearly, more research needs to be done on the positioning of the leg during the *osoto-gari* sweep. From the perspective of expertise, the black belt subjects should represent what is clearly a more proficient means to sweep an opponent, whether explained through biomechanical analysis or not. In this regard, the data can be a useful information for practicioners and coaches. According to the data collected for this study, optimal ankle and knee angles were 216.28 and 131.36 degrees, respectively. Illustratively, the positioning of joints closely represent a sickle used for reaping, consistent with the name "Major Outer Leg Reap" given many years ago (Figure 5).

Thus, questions still remain as to why experienced judoka choose to plantarflex their ankle during the downward sweeping motion of *osoto-gari*. Interestingly, the positioning of the leg is consistent with the definition of the throw, so named many years before the advent of biomechanical analysis of motion. In this regard, a reference to a curved blade (reaping by way of sickle) may have more significance than realized. The curved nature of many cutting blades have engineering and mechanical properties related to performance. It is possible that the sweeping leg can be considered similar in this regard. Likewise, this concept may serve as basis for future studies on the *osoto-gari* sweep.

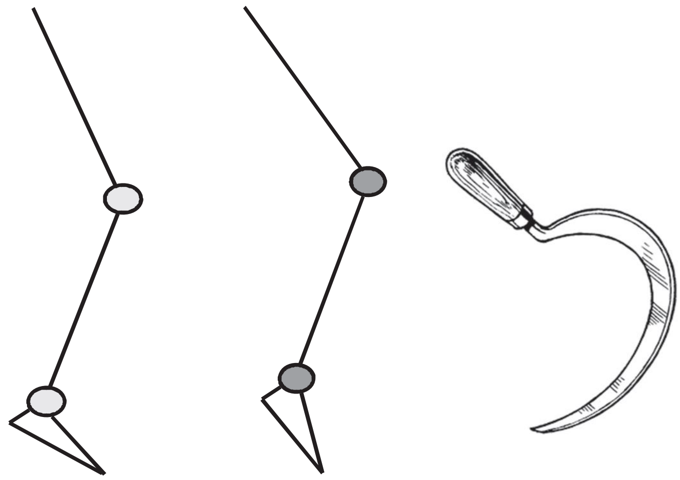

Figure 5. Illustration of average joint angles of the ankle and knee. From left to right, novice (ankle 239 degrees; knee 136 degrees) and black belt (ankle 216 degrees; knee 131 degrees). The black belt leg resembles a sickle’s blade.

References

Crawford, C.N.C. and James, N.T. (1980) . The design of muscles. In R. Owens, J. Goodfellow, and P. Bullough (Eds.) Scientific Foundations of Orthopaedics and Traumatology (pp. 67-74). London: William Heinemann.

Imamura, R.T. and Johnson, B.F. (2003) . A kinematic analysis of a judo leg sweep: major outer leg reap – osoto-gari. Sports Biomechanics, 2(2), 191-201.

Imamura, R.T., Iteya, M., Mandeville, D., and Parker, D.L. (2011) . Mechanical power of the sweeping leg during osoto-gari. Bulletin of the Association for Scientific Studies on Judo, Kodokan, XIII ( ).

Narazaki, N., Narazaki, K., and Stergiou, N. (2007) . Kinetic and kinematic analysis of judo throwing technique: osoto-gari. Bulletin of the Association for Scientific Studies on Judo, Kodokan, XI (19-31).