©Journal of Sports Science and Medicine (2008) **7**, 544-548
http://www.jssm.org

Research article

3D reconstruction of phalangeal and metacarpal bones of male judo players and sedentary men by MDCT images

Ibrahim Kalayci
Department of Geodesy and Photogrammetry, Faculty of Architecture and Engineering, University of Selcuk, Konya, Turkey

Abstract

This study has been performed to reveal hand bone peculiarities of elite male judoists by comparing their phalangeal and metacarpal bones with those of sedentary men on the basis of biometric ratio of the bones by means of three-dimensional (3D) reconstruction of multidetector computed tomography (MDCT) images. For this purpose, the axial images of the right and left hands of 8 elite male judo players (mean age: 22.0 ± 2.9 years, mean weight: 64.0 ± 4.9 kg) and 8 sedentary men (mean age: 26.0 ± 2.8 years, mean weight: 69.0 ± 3.6 kg) were obtained from MDCT. After semi-automatic segmentation and manual editing, the tracings of bone surfaces were stacked and overlaid to be reconstructed as the 3D images by the 3D program. All biometrical measurements of the reconstructed images of the bones were automatically calculated by this program to analyze statistically. This study showed that the differences between biometric ratios of judoist and sedentary men's hand bones were significant contrary to null hypothesis which was established as there is no difference between biometric hand bone ratios of these men of both groups. Therefore null hypothesis was rejected. Author suggests that intense clutching actions practised in judo sports can most probably lead to some hand bone proliferations. 3D reconstructed results belonging to the judo players and sedentary men help orthopaedists to diagnose pathological formations related to hand bones of judoists and may be used for anatomical education in medicine faculties, respectively. We hope that the results from the biometric and reconstructive techniques carried out in this work will contribute to the present knowledge on judoist and shed light on the future studies on sports medicine related to skeletal structure of other sportsmen.

Key words: CT imaging, three-dimensional reconstruction, judo players, sedentary men, morphometry.

Introduction

Among the contact sports it can be said that judo training has an advantage to represent physical fitness, motor skills and psychosocial attitude without serious injuries (May et al., 2001; Rogers, 1986). With this advantage a modified from of judo becomes a useful therapeutic, educational, and recreational tool for handicapped children (Caouette and Gijseghem, 1991; Gleser et al., 1992). Contrary to that, extensive judo practise has always a risk factor against to finger joints by developing osteoarthritis because of chronic repetitive and substantial injuries (Strasser et al., 1997).

In the literature some physiomorphological studies on judoists have been found. The researchers (Kubo et al., 2006) have investigated differences in fat-free mass and thicknesses of various muscles among judo athletes of different performance levels. Sekulic et al. (2006) presented better test results against to recreational players who took test for agility the sit-up test for abdominal muscle endurance, and the sit-and-reach test for flexibility. Moreover, they also stated that judo players maintained their skinfold thickness, whereas the recreational group showed a significant increase in skin fold thickness, and that no differences were observed between both groups in coordination, flexibility of the shoulder joint, speed, endurance, body height, and body weight. Kort and Hendriks (1992) stated that there were no significant differences between judo athletes of varying performance levels with respect to the ratios of flexion to extension and left to right rotations.

To date, in addition to the physiomorphological works mentioned above, a great number of psychophysiological (Filaire et al., 2001), neurological (Mikheev et al., 2002), biochemical (Salvador et al., 2003) and cardiac studies (Houvenaeghel et al., 2005) have been also carried out on judo sportsmen. However no comparative morphometrical study was found on hand bones of judo players and sedentary men. In this study, our aim is to provide a basic morphometric information (differences if there would be) on the hand bones of elite male judo players and sedentary men, investigating diversities related to biometric ratios of the phalangeal and metacarpal bones of both groups via 3D reconstruction of MDCT images.

Methods

Eight right-handed sedentary men (mean age: 26.0 ± 2.8 years, mean weight: 69.0 ± 3.6 kg) and eight right-handed elite male judo players who are members of Turkish National Judo Team (mean age: 22.0 ± 2.9 years, mean weight: 64.0 ± 4.9 kg) having no history and clinical signs of any orthopaedic disorder such as fracture, osteoarthritis or also acromegaly for giantism were included in this study. The procedures followed were in accordance with the ethical standards of the responsible committee of the faculty which are based on the Helsinki Declaration (Goodyear et al., 2007). The right and left hands of both groups were placed side by side in a prone anatomic position and were scanned by high resolution imaging using a general diagnostic MDCT (Somatom Sensation 64; Siemens Medical Solutions, Forchheim, Germany). Since the grasping tracksuit of rival with the palm is most frequently used by judoist, the metacarpal and phalangeal bones that form the palm have been included in the study, excluding the carpal bones. Scanning along the axial axis of the entire hand including the carpal joint was performed by using the following parameters: physical detector collimation, 32 x 0.6 mm; resulting section collimation, 64 x 0.6 mm; section thickness, 0.75 mm (increment, 0.7 mm); gantry rotation time, 330 msec; kVp, 120;

Received: 18 September 2008 / Accepted: 11 November 2008 / Published (online): 01 December 2008

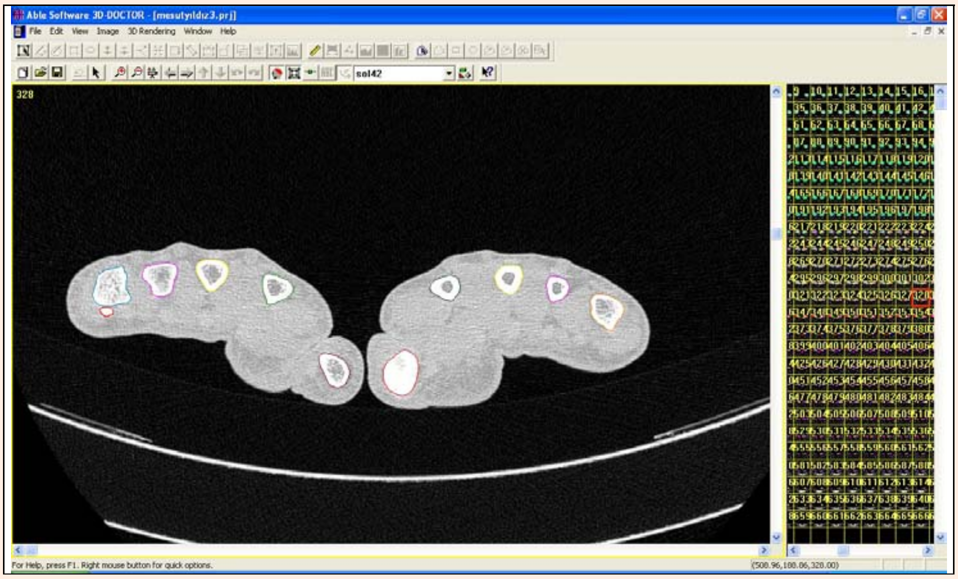

Figure 1. **Two-dimensional outlines that were defined manually.**

mA, 300; spatial resolution, 512 x 512 pixels with pixel spacing, 0.92 x 0.92 and radiometric resolution MONOCHROME2 which gives 16 bit gray level. Dose and scanning parameters have been performed by radiologists in Meram School of Medicine, University of Selcuk, Konya, Turkey, on the basis of the standardized protocol which considers the documented scanning practices and the recent studies (Prokop, M., 2003; Kalra et al., 2004) to generate optimum image quality while maintaining individual radiation exposure at the lowest level. The axial images obtained were then stored in DICOM format to transfer to a personal computer in which the 3D modelling software (3D-DOCTOR for Windows, Ay Tasarım Ltd., Ankara, Turkey, http://www.aytasarim.com) was set up. This study considered the manually corrected automated segmentation for 3D reconstruction of images as in the literature (Bazille et al., 1994). The points that have been improperly positioned after automatic boundary segmentation were edited manually throughout an interactive boundary editing routine; therefore this segmentation is called as semi-automatic segmentation. Manual editing process takes 3 to 4 minutes per image. Semi-automatic segmentation was done by determining the bone boundaries automatically first, then the points which were not correctly positioned on the bone boundaries were edited point by point with a computer mouse by only one and the same operator who was the author of the present study (Figure 1). After manual editing was rechecked visually, all the corrected boundaries of the bone surfaces were stacked and overlaid to reconstruct the 3D model of bones by 3D rendering component of the software (Figure 2).

Volume, surface area and length values of each

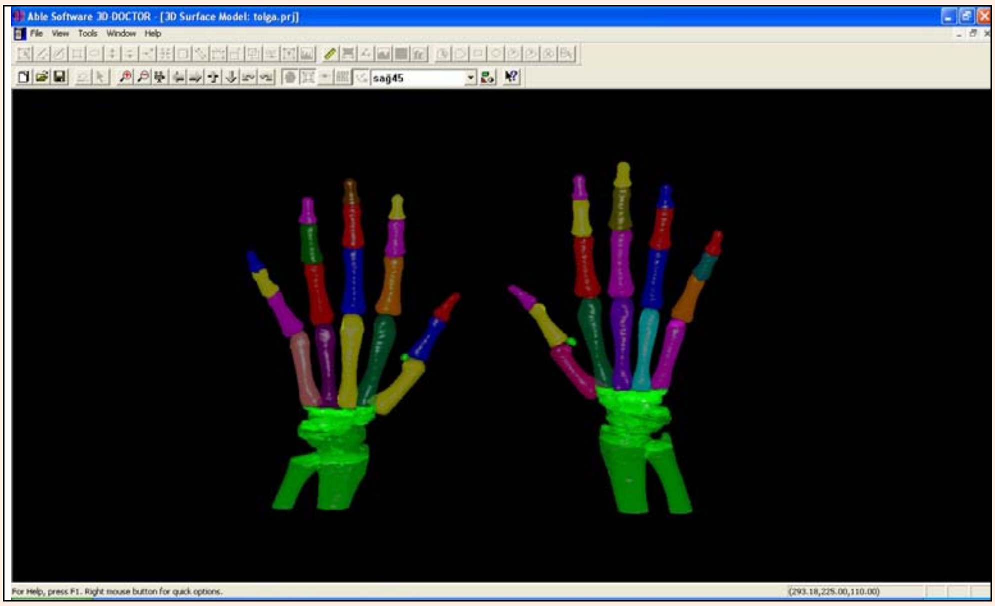

Figure 2. **3D reconstructed images of phalangeal and metacarpal bones.**

Table 1. **Parameters of phalangeal and metacarpal bones belonging to right hands of male judo players and sedentary men. Data expressed as the mean (±SEM).**

		Volume Ratio (%)		**Surface Area Ratio (%)**		**Length Ratio (%)**	
		Judo	**Sedentary**	**Judo**	**Sedentary**	**Judo**	**Sedentary**
Thumb	Proximal	71.5 (.8)	70.2 (.9)	65.9 (.7)	64.1 (.7)	59.5 (.8)	57.3 (.4) *
(*Digitus pirimus*)	Distal	28.5 (.7)	29.8 (.7)	34.1 (.6)	35.9 (.8)	40.5 (.4)	42.7 (.6) *
Fore finger	Proximal	66.7 (.7) *	68.9 (.8) *	58.3 (.6) *	60.7 (.5) *	50.7 (.8)	49.5 (.9)
(*Digitus secundus*)	Middle	24.7 (.8)	23.0 (.7)	28.4 (.8) *	26.4 (.6)*	30.5 (.5)	28.8 (.8) *
	Distal	8.6 (.9)	8.1 (.7)	13.3 (.5)	12.9 (.6)	18.8 (.6)*	21.7 (.6) *
Middle finger	Proximal	62.5 (.7) *	65.4 (.5) *	55.3 (.6) *	60.2 (.6) *	50.0 (.6) *	48.5 (.5) *
(*Digitus tertius*)	Medial	28.8 (.7) *	25.6 (.8) *	31.5 (.6) *	27.3 (.7) *	31.7 (.6)	31.8 (.6)
	Distal	8.7 (.4)	9.0 (.6)	13.2 (.6)	12.5 (.6)	18.3 (.8)	19.6 (.8)
Ring finger	Proximal	60.1 (.8) *	57.4 (.7) *	52.8 (.8) *	56.1 (.8) *	48.1 (.7)	46.8 (.8)
(*Digitus quartus*)	Middle	30.7 (.7)	32.1 (.8)	33.3 (.6) *	29.5 (.7) *	32.9 (.6) *	31.2 (.7) *
	Distal	9.2 (.7)	10.4 (.4)	14.0 (.8)	14.4 (.6)	19.0 (.8) *	22.0 (.7) *
Little finger	Proximal	60.6 (.8)	61.9 (.9)	53.7 (.7)	54.0 (.7)	47.1 (.8)	47.0 (.6)
(*Digitus quintus*)	Middle	26.7 (.5)	26.0 (.5)	28.8 (.7)	28.7 (.6)	27.5 (.6)	27.9 (.7)
	Distal	12.7 (.8)	12.2 (.6)	17.5 (.7)	17.4 (.8)	25.4 (.8)	25.1 (.7)
Metacarpal bones	1 st	18.4 (.7)	20.1 (.8)	17.7 (.8)	18.6 (.7)	16.0 (.7)	16.1 (.7)
	2 nd	22.9 (.7) *	25.0 (.5) *	23.4 (.6)	24.0 (.6)	22.4 (.4)	22.3 (.5)
	3 th	23.5 (.9)	24.3 (.9)	23.3 (.6)	23.4 (.7)	22.9 (.7)	22.6 (.7)
	4 th	16.3 (.8)	16.0 (.9)	18.1 (.7)	17.5 (.6)	20.4 (.7)	20.3 (.6)
	5 th	19.0 (.6) *	14.7 (.7) *	17.6 (.6)	16.6 (.6)	18.3 (.6)	18.7 (.7)

* means that differences among the means of different groups in the same row are statistically significant in value of $p < 0.05$. Rations were analyzed by t test.

phalangeal bone and each metacarpal bone were recorded in ratio comparison with each finger or total metacarpal bones, respectively. All measurements without considering the sesamoid bones were automatically calculated by this program. Statistical analysis was performed by using the Statistical Package for the Social Sciences (SPPS 9.0, SPPS Inc. Corp, Chiago, IL, USA) computer package. The mean values (MV) and standard error of means (SEM) were calculated. Significance was established at $p < 0.05$. It has been proposed that both biometric perspectives and 3D reconstruction technique performed in this work add a new dimension to the future studies on skeletal system of judo players and other sportsmen.

Results

Since individual morphometrical measurements (volume, surface area and length) of the bones that formed a hand were inherently different, and also it could be affected by individual physical and anatomical condition. Because of these reasons, in this study their mean measurements were not recorded as numeral. Instead of them, all values of each phalangeal bone and each metacarpal bone were given in ratio comparison with each finger or total metacarpal bones, respectively. Moreover, statistically important differences established at $p < 0.05$ have been interpreted in terms of ratios between the hand bones of both groups (refer to Tables 1 and 2).

Based on the data obtained from 3D reconstructed images, all the rations of the measurements of the right and left phalangeal and metatarsal bones belonging to the male judo players and sedentary men were shown in the tables 1 and 2 in detail. However, the outstanding statistical respects related to the volume, surface are and length rations between male judo players and sedentary men are stressed below:

Although only the length of the proximal and distal phalanges of the right thumb (*Digitus pirimus*) was statistically different, in the left thumb, both surface area and length had statistically important ratio-related-differences. The proximal phalanxes of the right and left forefingers (*Digitus secundus*) had statistically important ratio-related-differences in point of the volume and surface area. The surface area and length of the medial phalanx of the right and left forefingers including the volume of the medial phalanx of the left forefinger were statistically important. Moreover, it was interesting that the length of the distal phalanx of the right forefinger had a statistical difference. Although the volume and surface area of the proximal and medial phalanges belonging to the right and left middle fingers (*Digitus tertius*) were statistically different, the length of the proximal phalanx of the right one was also added to them. We have noticed with interest that there is a statistical importance in the surface area of the proximal and medial phalanges of both ring fingers (*Digitus quartus*). Although the length of the medial and distal phalanges of the right ring finger had a statistical importance, there is no difference in those of the left one. Moreover, the volume of the proximal phalanx of the right ring finger had also a statistical importance. Interestingly, the related biometrical values regarding the phalanges of the right little finger (*Digitus quintus*) had no statistical significance. However, in the volume and surface area of the proximal and medial phalanges of the left little finger and in the length of its medial and distal phalanges a statistical difference existed. There is a statistical significance between volumes of the right second and fifth metacarpal bones, while the volume of the left forth metacarpal bone had a statistical importance.

In terms of the volume, surface area and length, many biometric ratio values of some phalangeal and metacarpal bones of the elite male judoists have been found statistically significant when compared with those of the sedentary men. Therefore this case should be taken into consideration in orthopaedic procedures of judo players.

Table 2. Parameters of phalangeal and metacarpal bones belonging to left hands of male judo players and sedentary men. Data expressed as the mean (±SEM).

		Volume Ratio (%)		Surface Area Ratio (%)		Length Ratio (%)	
		Judo	Sedentary	Judo	Sedentary	Judo	Sedentary
Thumb	Proximal	69.6 (1.0)	69.8 (.7)	64.1 (.8) *	66.4 (.6) *	60.4 (.5) *	58.4 (.5) *
(*Digitus pirimus*)	Distal	30.4 (.8)	30.2 (.7)	35.9 (.8) *	33.6 (.7) *	39.6 (.7) *	41.6 (.6) *
Fore finger	Proximal	64.2 (.6) *	70.1 (.6) *	55.9 (.8) *	60.1 (.8) *	48.0 (.9)	49.0 (.7)
(*Digitus secundus*)	Middle	27.3 (.9) *	21.9 (.8) *	30.3 (.8) *	26.6 (.6) *	31.0 (.7) *	29.2 (.7) *
	Distal	8.6 (.8)	8.1 (.7)	13.7 (.6)	13.3 (.6)	21.0 (.8)	21.8 (.59
Middle finger	Proximal	61.3 (.6) *	68.8 (.4) *	58.2 (.7) *	62.5 (.7) *	48.1 (.6)	48.3 (.7)
(*Digitus tertius*)	Medial	29.4 (.8) *	23.2 (.6) *	29.2 (.7) *	25.7 (.6) *	33.5 (.9)	31.7 (.7)
	Distal	9.2 (.9)	8.0 (.6)	12.6 (.6)	11.8 (.8)	18.5 (.9)	20.0 (.7)
Ring finger	Proximal	59.5 (.6)	58.4 (.9)	53.0 (.6) *	55.2 (.7) *	48.2 (.7)	47.4 (.5)
(*Digitus quartus*)	Middle	30.5 (.9)	31.3 (.7)	32.4 (.7) *	29.9 (.8) *	31.5 (.9)	30.8 (.8)
	Distal	10.0 (.9)	10.4 (.5)	14.7 (.5)	14.9 (.8)	20.2 (.9)	22.0 (.7)
Little finger	Proximal	59.7 (.7) *	63.7 (.7) *	53.0 (.7) *	57.0 (.6) *	47.4 (.6)	47.9 (.5)
(*Digitus quintus*)	Middle	28.4 (.7) *	24.8 (.8) *	30.5 (.8) *	26.7 (.8) *	30.5 (.9) *	27.6 (.5) *
	Distal	11.9 (.5)	11.6 (.7)	16.5 (.7)	16.3 (.6)	22.1 (.7) *	24.5 (.7) *
Metacarpal bones	1 st	19.5 (.5)	20.4 (.6)	18.1 (.6)	19.0 (.6)	16.5 (.5)	16.0 (.7)
	2 nd	24.1 (.6)	25.5 (.5)	23.5 (.7)	23.9 (.8)	22.4 (.6)	22.7 (.8)
	3 th	24.2 (.6)	23.8 (.6)	23.4 (.6)	23.4 (.8)	23.1 (.6)	22.3 (.8)
	4 th	17.3 (.6) *	15.2 (.8) *	18.7 (.5)	17.3 (.7)	20.1 (.6)	20.1 (.5)
	5 th	15.0 (.6)	15.1 (.8)	16.3 (.6)	16.3 (.7)	18.0 (.4)	18.8 (.6)

* means that differences among the means of different groups in the same row are statistically significant in value of $p < 0.05$. Rations were analyzed by t test.

Discussion

Computed tomography (CT) is an effective diagnostic modality for 2D multiplanar images (coronal, sagittal, axial) of bone structures, including their defects (Krupa et al., 2007). The MDCT, a recent technologic advance, can obtain a large number of 2 D images during one rotation of the X-ray tube, making it possible to get thin slices within a short scan time. By means of different software developed in last years, pseudo-3D displays are also created from a stack of 2D images of a large number of these parallel planes as snapshots (Hu et al., 2000). It is possible to use 3D software not only for 3D visualization of tissues but also for their 3D geometrical modelling which is mathematical, vector based description of tissue-boundary geometry (Cernochova et al., 2005; Krupa et al., 2004; 2007). They also stressed that the 3D geometrical technique has steadily become more applicable to simulations, navigations and training particularly in plastic surgery, stomatology, orthopaedic surgery, traumatology, neurosurgery, etc.

In the present study, since the semi-automatic segmentation procedures on 2D CT images make some incorrect label assignment, the manual editing has been also added to the image processing procedure to reveal nearly absolute 3D images and geometrical measurements of the phalangeal and metacarpal bones. Therefore, it can be said that the 3D reconstructed images and findings from this study reflect accurately the true anatomical properties of the related-bones. By using 3D reconstructed results of this study, it may be easy to diagnose pathological formations related to the hand bones of judo sports thus suggesting the appropriate treatment plans. Moreover, based on 3D geometrical bone models belonging to sedentary men, plastic hand models of real dimension can possibly be created. Finally, as long as the medical imaging and photogrammetry reasonably approximate each other, it may be possible to create new approaches for sports medicine.

It is true that this study have limitations depending on the manual editing, which introduces operator-dependency and time consumption, and the technique may not be suitable for routine evaluation of hand bones of judoist or sedentary men. Nevertheless, in this study our main purpose has already been to provide basic morphometric information regarding the hand bones of judo players and sedentary men by means of 3D reconstruction of MDCT images, and also to reveal if judo sports have negative effects on metacarpal and phalangeal bones.

Regarding the volume, surface area and length, most of the judo player's biometric ratio values, which were found higher than those of the sedentary men, were statistically important as compared with those of sedentary men. Therefore we suggested that judoists have possibly the hand bone proliferation in comparison with sedentary men. However, as the validation of the data is necessary before being broadly applied on a clinical basis, further reconstructive, pathological and biomechanical studies are required to reveal definitely the exact reason of some metacarpal and phalangeal bone proliferations in judo players. We are also planning a further similar study on different sportsmen such as weight lifter and wrestler.

Conclusion

This study showed that biometric rations of the metacarpal and phalangeal bones of elite judo players have higher that those of sedentary men, which is statistically important, therefore this respect should be considered in medical procedures regarding the hand skeleton of judoists.

Acknowledgements

The author is grateful to Dr. Muzaffer SEKER and Dr. Emrullah EKEN (who are anatomists in Selcuk University) for their technical and linguistic help, and to Dr. Yalçın KAYA who brought me all MDCT images.

References

Bazille, A., Guttman, M.A, McVeigh, E.R. and Zerhouni, E.A. (1994) Impact of semiautomated versus manual image segmentation errors on myocardial strain calculation by magnetic resonance tagging. *Investigative Radiology* **29,** 427–433.

Caouette, M. and Gijseghem, H. (1991) Judo as a therapeutic activity for the young delinquent. *Revue Canadienne de Psycho-Education* **20,** 99-108.

Cernochova, P., Kanovska, K., Krsek, P. and Krupa, P. (2005) Application of geometric biomodels for autotransplantation of impacted canines. In: *World Journal of Orthodontics*. Quintessence Publishing Co, p. 1, ISBN 1530-5678, Paris.

Filaire, E., Sagno, M., Ferrand, C., Maso, F. and Lac, G. (2001) Psychophysiological stres in judo athletes during competitions. *Journal of Sports Medicine and Physical Fitness* **41,** 263-268.

Franchini, E., Takito, M.Y., Kiss, M.A.P.D.M. and Sterkowics, S. (2005) Physical fitness and anthropometrical differences between elite and non-elite judo players. *Biology of Sport* **22,** 315-328.

Gleser, J.M., Margulies, J.Y., Nyska, M., Porat, S., Mendelberg, H. and Wertman, E. (1992) Physical and psychosocial benefits of modified judo practice for blind, mentally-retarded children - A Pilot-Study. *Perceptual and Motor Skills* **74,** 915-925.

Goodyear M.D., Krleza-Jeric K. and Lemmens, T. (2007) The Declaration of Helsinki. *British Medical Journal* **335,** 624-625.

Houvenaeghel, M., Bizzari, C., Giallurachis, D. and Demelas, J.M. (2005) Continuous recording of heart rate during specific exercises of judo. *Science & Sports* **20,** 27-32.

Hu, H., He, H.D, Foley, W.D. and Fox, S.H. (2000) Four multidetector-row helical CT: Image quality and volume coverage speed. *Radiology* **215,** 55-62.

Kalra, M.K, Maher, M.M., Toth, T.L., Hamberg, L.M., Blake, M.A., Shepard, J. and Saini, S. (2004) Strategies for CT radiation dose optimization. *Radiology* **230,** 619-628.

Kort, H.D. and Hendriks, E.R.H.A. (1992) A comparison of selected isokinetic trunk strength parameters of elite male judo competitors and cyclists. *Journal of Orthopaedic & Sports Physical Therapy* **16,** 92-96.

Krupa, P., Krsek, P., Cernochova, P. and Molitor, M. (2004) 3D real modelling and CT biomodels application in facial surgery. In: *Neuroradiology* European Society of Neuroradiology, ISBN 0028-3940, S141-1 p. , Berlin..

Krupa, P., Krsek, P., Javornik, M., Dostal, O., Srnec, R., Usvald, D., Proks, P., Kecova, H., Amler, E.,Jancar, J., Gal, P., Planka, L. and Necas, A. (2007) Use of 3D geometry modelling of osteochondrosis-like iatrogenic lesions as a template for press-and-fit scaffold seeded with mesenchymal stem cells. *Physiological Research* **56 (Suppl. 1),** 107-114

Kubo, J., Chishaki, T., Nakamura, N., Muramatsu, T., Yamamot, Y., It, M., Saitou, H. and Kukidome, T. (2006) Differences in fat-free mass and muscle thicknesses at various sites according to performance level among judo athletes**.** *Journal of Strength and Conditioning Research* **20,** 654-657.

May, T.W., Baumann, C., Worms, L., Koring, W.and Aring, R. (2001) Effects of judo training on physical coordination and body sway in adolescents and young adults with multiple impairments and epilepsy. *Deutsche Zeitschrift fur Sportmedizin* **52,** 245-51.

Mikheev, M., Mohr, C., Afanasiev, S., Landis, T. and Thut, G. (2002) Motor control and cerebral hemispheric specialization in highly qualified judo wrestlers. *Neuropsychologia* **40,** 1209-1219.

Prokop, M. (2003). General principles of MDCT. *European Journal of Radiology* **45,** S4-S10.

Rogers, C.C. (1986) Judo - A Sport fit for everybody. *Physician and Sportsmedicine* **14,** 170-175.

Salvador, A., Suay, F., Gonzalez-Bono, E. and Serrano, M.A. (2003) Anticipatory cortisol, testosterone and psychological responses to judo competition in young men. *Psychoneuroendocrinology* **28,** 364-375.

Sekulic, D., Krstulovic, S., Katic, R. and Ostojic, L. (2006) Judo training is more effective for fitness development than recreational sports for 7-year-old boys. *Pediatric Exercise Science* **18,** 329-339.

Strasser, P., Hauser, M., Häuselmann, H.J., Michel, B.A., Frei, A. and Stucki, G. (1997) Development of finger-joint osteoarthritis in judo. *Zeitschrift fur Rheumatologie* **56,** 342-350.

Key points

- Image processing of hands of sedentary man and male judo players.
- 3D models of hands of those men by using MDCT images.
- The results from those models compared in terms of volume, surface areas, and length changes for all individual hand bones.

AUTHOR BIOGRAPHY

Ibrahim KALAYCI

Employment

Assistant Professor, Department of Geodesy and Photogrammetry, Faculty of Architecture and Engineering, University of Selcuk, Turkey.

Degrees

PhD

Research interests

Image processing, GPS application

E-mail: ikalayci@selcuk.edu.tr

✉ **Ibrahim Kalayci**

Department of Geodesy and Photogrammetry, Faculty of Architecture and Engineering, University of Selcuk, Campus, Konya, Turkey