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Body Asymmetries in Young Male Road Cyclists

Asimetrías Corporales en Ciclistas de Carretera Masculinos Jóvenes

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SUMMARY: An anthropometric analysis was conducted on 64 competitive young male road cyclists of different age categories (U17; U19; & U23 years of age). The purpose of the study is to find asymmetries between the left and right side of upper and lower limbs with the NX-16 (TC[2]) 3D body scanner, which includes measurement of left and right upper arm girth, elbow girth, forearm girth, wrist girth, thigh girth, knee girth, thigh length, calf girth, and shin length. Body composition was measured by the bioelectrical impedance machine InBody 720 (Biospace Ltd.). Results of body composition measurements of male road cyclists showed that U17 and U19 youth road cyclist differed statistically in five (from 11) paired variables, and the U23 age group differed statistically in six (from 11) paired variables. All of the age groups differed statistically in elbow, forearm, and calf girth. The main finding of study was that as the age of a cyclist increases, there is a tendency to increase asymmetries between the left and right side of several body segments.

KEY WORDS: Morphology; Anthropometry; Circumferences; Cycling; Symmetry.

INTRODUCTION

Road cycling is one of the most widespread types of cycling, and usually leads young cyclists through the junior category towards a goal that represents a professional level of road cycling (Menaspà *et al*., 2012). For cycling as an edurance sport, a variety of different anthropometric characteristics, training characteristics, and physiological variables have been identified as important predictors for race performance (Knechtle, 2014). Over the years, research has been conducted in an attempt to provide further insight into the extent that an athlete's body dimensions and composition influence performance (Stöggl *et al*., 2010). In cycling, it was demonstrated that individuals competing in sprint events possess a higher body mass and larger leg circumferences than distance cyclists (McLean & Parker, 1989). However, each form of cycling elicits different physical adaptations on the cyclist's body, and road cycling tends to increase aerobic capacity by increasing the lean body mass in order to produce more power (Hawley & Stepto, 2001; Zaton & Dabrowski, 2013). A working group of the International Olympic Committee the Medical Commission recently confirmed cycling is a weight-sensitive sport, so the importance of morphology and body dimensions is even greater (Haakonssen *et al*. 2015).

During cycling, bilateral differences are frequently found and vary with the competitive situation, pedalling cadence, exercise intensity, and exercise duration (Carpes *et al*., 2010). Cycling and other sports with repetitive movements can cause muscle force and/or flexibility asymmetries (Tashiro *et al*., 2016) that can lead to body asymmetries. Long-lasting and regular training sessions along with the intensive, and at the same time asymmetrical, muscle work may cause different types of overloads which lead to different motor organ injuries and deformations (Barczyk-Pawelec *et al*., 2012). Therefore, the necessity to measure body asymmetries in road cycling is even more important. Anthropometry is considered to be one of the most classical methods for assessing the dimensions of body segments (Heyward & Wagner, 2004), and has been often used in road cycling (Zaton *et al*., 2014; Iriberri *et al*., 2008). But nowadays, methods for obtaining anthropometric body data have become more practical, contactless, fast, and, above all, accurate since the introduction and application of 3D body scanners (Simmons & Istook, 2003; Simenko & Cuk, 2016). A construction and comparison of composite shape models represents an additional advantage of 3D scanning. This advantage could be utilized in a wide variety of digital shape outputs that can extend to 2D or 3D format with an electronic

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archiving of scans, which could be utilized in future analysis with improved software (Wells *et al*., 2015). After reviewing the literature, the 3D scanning method has been rarely used in cycling (Bullas *et al*., 2014; Daanen *et al*., 2016), but it has been frequently used in other sports (Schranz *et al*., 2010; Simenko & Vodicar, 2015) and other fields (Treleaven & Wells, 2007; Sims *et al*., 2012; Wells *et al*.).

With this in mind, we reviewed the available literature and concluded that there is a lack of studies which would explore the impact of road cycling on morphological asymmetries. Therefore, a fast and reliable method, such as 3D body scanning analysis, can be a useful tool in determining body asymmetries that can lead to the occurrence of injuries.

MATERIAL AND METHOD

Subjects. This study included 64 participants (male road cyclists) of different age categories (U17 (n=27), U19 (n=17), & U23 (n=20)). Their mean age was 17.2± 2.45 years, their body height 176.2±7.1 cm, and their body weight was 62.7±7.3 kg. Written informed consent was obtained from all participants.

Anthropometric measurements: Body height was measured with an anthropometer GPM (Switzerland). Measurements of body composition were performed using bioelectrical impedance analysis (BIA), with the InBody 720 Tetrapolar 8-Point Tactile Electrode System (Biospace Co., Ltd.). The InBody 720 apparatus utilizes the technology for measuring body composition by using the method of Direct Segmental Multi-Frequency Bioelectrical Impedance Analysis. With InBody 720 we measured body weight, body mass index (BMI), skeletal muscle mass (SMM), body fat mass (BFM), total body water (TBW), right and left arm lean mass (RALM, LALM), and right and left leg lean mass (RLLM, LLLM).

3D body scan measurements: 3D anthropometric body measurement was performed by the 3D body scanner NX-16 ([TC]2, Cary, North Carolina), which was validated in a previous study (Simenko & Cuk) and represents a non-invasive scanning method to produce a true-to-scale 3D body model in 8 seconds. The scanner uses photogrammetry technology, which projects patterns of structured white light on to the body. The way in which the pattern is distorted by the shape of the body is then recorded by 32 cameras. From this, the body shape is digitally reconstructed from a raw photonic point cloud data, which leads to a surface reconstruction of the body and allows for automatic landmark recognition as well as electronic tape measurements. With the software we extracted the measurements of nine paired measurements of left and right upper arm girth, elbow girth, forearm girth, wrist girth, thigh girth, knee girth, thigh length, calf girth, and shin length. Shin length was calculated as the distance between ankle height and knee joint height variables, which were also extracted from the 3D scan.

Experimental procedure. The subjects were measured by the same examiner, one with extensive experience in the physiological laboratory at the Faculty of Sport, University of Ljubljana, in controlled environment conditions.

Before measurements, full calibration of the NX-16 scanner was made. Full calibration was done using: 1) the reference cylinder which was 150 cm in height and had diameter of 28 cm, and 2) additional set of reference balls which included two strings of calibration balls and a single calibration ball (diameter of all balls was 15 cm). The scanner calibrated itself in a way that it measured a circumference on every 10 mm from top to bottom of the cylinder, and also calculated circumferences standard deviation that should not have exceeded the prescribed limits of 0.9 mm (Simenko & Cuk). Calibration with a string of balls was successful and within the acceptable range of the circumferences standard deviation of 0.417 mm.

Further, subjects were instructed to remove all jewelry and clothes. They entered the scanner barefooted and in form-fitting bright colour underwear. They stood in a standardized position, with their feet located on landmarks on the scanner's floor (feet set straight, not inwards or outwards), grabbing the handles inside of the scanner with a natural standing posture (shoulders not elevated, elbows stretched, upright position of the back, chin slightly lifted). Subjects with long hair were instructed to tie their hair in a bun (Simenko & Cuk).

A 3D Body Measurement System Version 7.4.1 software was used to create the initial point cloud that was then processed into a 3D body model, from which customized measurements could be extracted. A multi-scan option with three consecutive scans was used to obtain the data. Multi-scan options merged all three files of three consecutive scans and gave one merged file with the means of all three consecutive scans. Scanning of the three consecutive scans lasted 24 s and subjects were instructed to be still as much as possible (Simenko & Cuk).

Statistical Analysis. Analyses were conducted using SPSS for Windows (Version 21.0; SPSS, Inc., Chicago, USA). Data were presented according to descriptive statistics (Means ± SD). Furthermore, we performed the following tests: Kolmogorov-Smirnov test, standard error of measurement (SEM), and a paired sample T-test. All statistical significance for the t-test was set to $p<0.05$.

RESULTS

Table I shows descriptive statistic of anthropometric characteristics and body composition of male road cyclists (Body height, Body weight, BMI, BF (body fat mass), SMM (skeletal muscle mass), and TBW (total body water). Results show statistical significant differences between different age categories in body height, body weight, and skeletal muscle mass, where there has been an increase with aging.

Table II-IV shows body composition and 3D anthropometric measurement of different body segment. We made an analysis for body segments which might be important for cycling. Table II shows results and some statistical significant differences between the left and right sides of different body segments among cyclists of age group under 17. The statistical differences were found in five paired variables: upper arm girth t(26)=2.66, p= 0.013; elbow girth t(26)=4.58, p= 0.000; forearm girth t(26)=6.97, p= 0.000; knee girth t(26)=4.71, p= 0.000; and calf girth t(26)=3.79, p= 0.001. Close to the limit of statistical significance in U17 age group is thigh length variable p= 0.054.

Table III shows results and some statistical significant differences between left and right side of different body segments among cyclists of age group under 19. The statistical differences were found in five paired variables: elbow girth t(16)=4.15, p= 0.001; forearm girth t(16)=3.92, p= 0.001; Leg lean mass t(16)=2.14, p= 0.048; thigh girth t(16)=3.09, p= 0.007; and calf girth t(16)=5.07, p= 0.000.

Table IV shows differences among the cyclists of age group of U23 years. The statistical differences were found in six paired variables: arm lean mass t(19)=3.28, p= 0.004; elbow girth t(19)=4.71, p= 0.000; forearm girth t(19)=5.39, p= 0.000; Leg lean mass t(19)=4.00, p= 0.001; knee girth t(19)=5.15, p= 0.000; and calf girth t(19)=5.41, p= 0.000. Results shows statistical differences between the left and right sides of anthropometric measurements (Elbow girth, Forearm Girth, Knee Girth, Calf Girth), and also among the measurement of body composition between left and right arm and leg lean mass.

Table I. Anthropometry and body composition.

Variables	AGE Group/Category										
	U 17		U19		U23		95% CI				
	Mean	SD	Mean	SD	Mean	SD	Lower	Upper	*df*	*t*	*p*
Height (cm)	176.2	7.1	178.9	6.7	181.0	4.6	176.8	180.0	63	3.39	**.040**
Weight (kg)	62.7	7.3	67.1	6.2	69.4	5.6	64.2	67.7	63	6.46	**.003**
BMI	20.1	1.5	20.9	1.0	21.2	1.4	20.3	21.0	63	3.91	**.025**
BF (%)	5.9	1.4	6.6	1.7	7.0	1.9	6.0	6.8	63	2.823	.067
SMM (kg)	31.9	3.9	34.1	3.4	35.4	3.0	32.6	34.5	63	5.81	**.005**
TBW (kg)	41.8	4.8	44.4	4.2	45.8	3.6	42.6	44.9	63	5.38	.007

Table II. Anthropometry among age group U17 selected paired variables.

Variable	AGE Group/ U 17						
	Left		Right				
	Mean	SD	Mean	SD	*df*	*t*	*p*
Arm Lean Mass	3.13	0.49	3.15	0.51	26	1.66	.108
Upper arm Girth	28.01	2.09	28.49	2.36	26	2.66	**.013**
Elbow Girth	24.82	1.47	25.35	1.19	26	4.58	**.000**
Forearm Girth	25.21	1.59	25.93	1.51	26	6.97	**.000**
Wrist Girth	17.03	0.80	16.92	0.68	26	0.88	.387
Leg Lean Mass	9.08	1.15	9.09	1.15	26	0.85	.403
Thigh Girth	59.85	5.23	59.79	5.16	26	0.22	.826
Knee Girth	37.28	1.69	37.65	1.74	26	4.71	**.000**
Calf Girth	35.33	1.91	35.73	1.89	26	3.97	**.001**
Thigh Length	35.86	4.75	35.95	1.89	26	2.01	.054
Shin Length	42.71	4.28	42.67	4.27	26	1.26	.232

Table III. Anthropometry among age group U19 selected paired variables.

Variable	AGE Group/ U 19						
	Left		Right				
	Mean	SD	Mean	SD	*df*	*t*	*P*
Arm Lean Mass	3.35	0.42	3.35	0.39	16	0.02	.982
Upper arm Girth	28.64	1.17	28.62	1.57	16	0.07	.945
Elbow Girth	25.07	0.97	25.64	0.94	16	4.15	**.001**
Forearm Girth	25.65	1.06	26.15	1.05	16	3.92	**.001**
Wrist Girth	16.98	0.99	16.80	0.70	16	0.51	.255
Leg Lean Mass	9.65	1.18	9.69	1.17	16	2.14	**.048**
Thigh Girth	59.95	4.24	59.76	4.57	16	3.09	**.007**
Knee Girth	37.73	1.69	38.08	1.64	16	2.05	.672
Calf Girth	35.82	1.86	36.40	1.86	16	5.07	**.000**
Thigh Length	35.36	4.06	35.40	4.08	16	0.43	.672
Shin Length	42.30	4.08	42.31	4.06	16	0.31	.756

Table IV. Anthropometry among age group U23 selected paired variables.

Variable	AGE Group/ U 23						
	Left		Right				
	Mean	SD	Mean	SD	*df*	*t*	*p*
Arm Lean Mass	3.48	0.39	3.53	0.39	19	3.28	**.004**
Upper arm Girth	29.01	1.59	29.18	1.72	19	1.09	.291
Elbow Girth	25.41	0.95	25.95	0.96	19	4.71	**.000**
Forearm Girth	25.93	1.23	26.64	1.26	19	5.39	**.000**
Wrist Girth	16.47	0.82	16.56	0.81	19	0.98	.337
Leg Lean Mass	9.95	0.83	10.03	0.81	19	4.00	**.001**
Thigh Girth	60.06	4.97	60.38	4.67	19	0.99	.333
Knee Girth	38.15	2.98	38.75	3.09	19	5.15	**.000**
Calf Girth	36.06	2.31	36.68	2.43	19	5.41	**.000**
Thigh Length	35.77	4.32	35.89	4.28	19	2.16	.440
Shin Length	43.65	3.80	43.61	3.82	19	1.79	.088

DISCUSSION

Carpes *et al*. explained that among the humans there is a tendency to preferentially use one side of the body in a voluntary act. This tendency characterizes the lateral preference. Lateralization has been suggested to be only 10-20 % dependent on genetics. Other influences such as task complexity, gender, and developmental characteristics play an important role for body side choice. Among the few studies considering the bilateral assessments of pedalling, data are consistent in showing that cyclists present frequent asymmetry. The amount of asymmetry can vary within subjects and the limb producing asymmetry. They continued that pedalling asymmetry appears to be related to limb preference and is significantly reduced with an increase of pedalling workload. Differences between lower limbs may remain constant across the age span (Teixeira & Teixeira, 2008). In contrast, Muyor *et al*. (2012) explained that aging is a conditional factor to the sagittal spinal morphology and pelvic tilt in cyclists.

Tables I, II, III, and IV all measured and showed a comparison of selected anthropometric characteristics between different age groups of male road cyclists. Results of body height and body weight according to the age category of male road cyclists showed similar trends to those exhibited in previous studies with road cyclists (Menaspà *et al*.; Zaton *et al*.). For example, track cyclists were found to have higher body weight with more skeletal muscle mass, which might be explained by the performance characteristics of the cycling discipline (McLean & Parker). To estimate body composition measurement, we used bioelectric impedance analysis (BIA). Among the cyclists we found that body fat percentage remains the same with aging, from age category under 17 years until the age category under 23 years. The opposite was found with the skeletal muscle mass by the cyclists, which significantly increased with aging. We also found asymmetries between left-right side of leg and arm lean mass among the cyclists of age category under 23 years in comparison to the cyclists of age category under 17 years. Anthropometric measurement was performed by a 3D body scanner, a relatively new method of anthropometric measurements. Simenko & Cuk validated the 3D body measurement and estimated high ranking consistency with manual anthropometry. For the purpose of our study we measured nine paired variables (Girth of upper arm, elbow, forearm, wrist, thigh, knee and calf; Length of thigh and shin).Results of the road cyclists showed that all measurements except the upper arm girth significant increase with aging. Results showed asymmetry between left and right limb measurements. Knee and calf girth were significantly different among all three age categories of road cyclists. There were very similar differences between the left and right sides of body segments among the cyclists of age group u17 and U19. Among both groups there were statistical differences between left and right elbow girth, forearm girth, knee girth, and calf girth. Asymmetries between left and right side were also noticed in the upper limbs, where we found asymmetries between elbow, forearm, and wrist girth among all three age categories of road cyclists. In conclusion, there is a tendency to increase asymmetries between left and right side of several body segments as the age of cyclists increases. This could be explained by the training load, which progressively increased. Pinnot & Grappe (2015) explained the annual training duration increased with the mean weekly duration increasing from 10.1 h in the junior category, to 18.1 h in the elite (pro-tour cyclists) category.

The main goal of the study found anthropometric asymmetries between the left and right sides of the upper and lower limbs measurements among male road cyclists of different age categories. The limitations of our study were in the fact that we made a comparison of different road cyclists. For future research it might be better to use longitudinal study with the same road cyclists, following their progress from junior to the elite level of cycling. Also the question, if those asymmetries lead to a greater occurrence of injuries or a bigger drop out, or if they can be related to better cycling performance still needs to be further researched.

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RESUMEN: Se realizó un análisis antropométrico de 64 ciclistas hombres, competidores de carretera, de diferentes categorías de edad (M17 y M23 años). El objetivo del estudio fue encontrar asimetrías entre el lado izquierdo y el lado derecho de los miembros superiores e inferiores con escáner corporal NX-16 (TC2) 3D, que incluyó la medición de las circunferencias izquierda y derecha de la parte superior del brazo, circunferencia del codo, circunferencia del antebrazo, y de la muñeca, circunferencia del muslo, de la cintura y de la rodilla; se midió el largo del muslo, circunferencia de la pantorrilla y el largo de la tibia. La composición corporal se midió mediante la máquina de impedancia bioeléctrica InBody 720 (Biospace Ltd.). Los resultados de las mediciones de la composición corporal de los ciclistas de carretera mostraron que los ciclistas juveniles de las categorías M17 y M19 difirían estadísticamente en cinco (de 11) variables pareadas, y el grupo de edad de los 23 años difirió estadísticamente en seis variables. Todos los grupos etarios difirieron estadísticamente en el codo, el antebrazo y en la circunferencia de la pantorrilla. El principal hallazgo del estudio indicó que al aumentar de edad un ciclista, se observa un aumento de la asimetría entre los lados izquierdo y derecho de varios segmentos corporales.

PALABRAS CLAVE: Morfología; Antropometría; Circunferencias; Ciclismo; Simetría.

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