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A method for the analysis of cyclist shorts with different pads for perineal area protection: comparison between drum and road tests

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Abstract

Aim of the present study was to develop an integrated protocol consisting on drum indoor tests and road outdoor tests to quantify the compression of the cyclist perineal zone. During indoor tests 5 cyclists performed 3 trials with different shorts on a cycling drum simulator: the pressure distribution between the saddle and the bottom of the cyclist, and the 3D pelvic motion were synchronously recorded. In the outdoor tests three of the five cyclists performed 5 trials for each shorts at the same speed and cadence of the indoor tests on a flat tarmac road including three potholes in each trial. Finally the pads were mechanically tested with a cyclic fatigue test. Results allowed to have more precise information about the pressure distribution acting on the perineal area in different conditions and to define significant loading cycles for the fatigue testing of the shorts padding material.

Keywords: cycling; perineal pressure distribution; shorts padding; drum simulator; outdoor.

1. Introduction

Cycling is one of the most popular sport and fitness activity: several factors like its great diffusion on road and off-road tracks, the direct contact of body segments over small areas of the bicycle and the high intensity of exercise involved can explain the diffusion of chronic overuse injuries especially to hands, wrists, knees and perineal area. We focused our attention upon bicycling related overuse injuries affecting the genitourinary tract because of their effect on the reduction of the quality of life. The most common problems are nerve entrapment syndromes presenting as genitalia numbness followed by erectile dysfunction as frequently reported in literature [1,2,3,4]. The

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most involved nerve is the pudendal nerve which innervates the perineum and the genitalia: because of its course in the pelvis, it is compressed near the ischiatic tuberosity and the pubic symphysis while pedalling sitting on a typical hard narrow road saddle. The compression of the perineal area can lead to arterial insufficiency, another possible cause of genital numbness and impotence [1,5]. In view of the relevance of the problem, previous studies have analyzed the effect of different saddle geometries on the effectiveness of reducing perineal compression [6,7,8].

Aim of the present study was to develop an integrated protocol consisting on drums indoor tests and road outdoor tests to quantify the compression of the cyclist perineal zone using three shorts with different padding. A second purpose of this study was to use pressure data collected to mechanically test the three different pads with a cyclic fatigue test quantifying the variation in thickness, stiffness and damping during the application of a high number of load cycles.

2. Materials and Methods

2.1. Instrumentations

Saddle pressure measurement was made with the Pliance X-32 pressure sensor system (Novel, Germany) and its bicycle pressure mat S2019 of 234 square capacitive sensors (1.875x1.875cm). It was calibrated to 400 kPa and the sampling rate was set at 60 Hz in the indoor tests and at 50 Hz in the outdoor tests. A stereophotogrammetric system (BTS, Italy) composed by 6 cameras working at 60 Hz was used to record the 3D kinematics data during the indoor tests. Each cyclist performed all tests with its own bicycle that was fixed on a Real Power cycling drum simulator (Elite, Italy) during the indoor sessions. In the outdoor tests a goniometer placed on the lateral side of the right knee was connected to a PDA PocketEMG (BTS, Italy) to record the knee flex-extension synchronously with the saddle pressure data. Finally the mechanical characterization of the different shorts was made by means of a MTS Mini Bionix II device.

2.2. Test protocol

Five semi-professional cyclists (age 25.8±4.8; height 175.6±3.6 cm; weight 66.4±3.4 kg) were involved in the study. Before starting the experimentation they were asked to read and sign an informed consent. The first step of the indoor test protocol consisted on the placement of the reflective markers in specific anatomical points: 2 at the posterior superior iliac spines (PSIS), 2 at the anterior superior iliac spines (ASIS), 2 at the heels and 2 at the metatarsal head of the fifth toe. Then the bike of each tester was hooked on the cycling drum simulator and the sensor pressure mat fixed on the saddle. Each cyclist completed 3 trials, each one with a different shorts assigned in a randomized way. The pedalling trial consisted on 10 km at a constant speed of 30 km/h with the same gear (53x18), sitting with hands positioned at the top of the handle bar for all the time. Kinematics and pressure data were synchronously recorded every five minutes for forty-five seconds.

In the outdoor test, after the placement of the goniometer on the lateral side of the right knee and of the pressure mat on the saddle, cyclists performed 5 pedalling trials for each type of shorts at the same speed and cadence of the indoor test on a flat tarmac road of 250 meters. Three potholes were also included in each trial.

To test the three different pads on the MTS Mini Bionix II device a fatigue test was defined: a fatigue block of 10000 cycles with load ranging from 300 N to 4500 N at 6 Hz was repeated for 10 times for a total number of 100000 cycles. The fatigue test was repeated three times for each pad with a constant rest of 30 minutes for a total number of 300000 cycles. The load range was chosen after analyzing peak pressure data collected during the potholes going through.

2.3. Data analysis

2.3.1. Indoor drum and road tests

The creation of a sensor mask with a dedicated Novel software which reproduced the effective contact area between the bottom of the cyclist and the saddle was the first step of the analysis. Then we decided to concentrate our analysis on the first 30 pedalling cycles for the drum tests and the first 15 for the road tests. The indoor pedalling cycle was defined between two consecutive top dead centers (TDC) looking at the vertical coordinate of the marker placed at the right metatarsal head of the fifth toe while in the road test the cycle was defined between two consecutive bottom dead centers (BDC) looking at the maximum extension value of the goniometer placed on the lateral side of the right knee. Kinematics data relative to 3D pelvis motion were synchronized with pressure mat data and referred to the same 30 indoor pedalling cycles.

Our integrated protocol considered the following variables: vertical force, mean and peak pressure, pelvic tilt, pelvic obliquity and pelvic rotation. In particular the vertical force was computed as the integral of the pressure referred to the contact saddle area frame by frame; the mean pressure was defined as the frame by frame mean of the pressure values among all the sensors of the sensor mask; finally the peak pressure indicated for each frame the highest value of pressure. In the indoor drum tests we computed the average of these variables among the runs at minute 5, 10, 15 and 20. Then a final grand mean of each variable was computed to compare the three different shorts tested. On the other hand in road tests the grand mean referred only to pressure data and was computed among the five runs performed by each cyclist with the three shorts.

2.3.2. Fatigue test

The wave function used for each of the ten fatigue blocks of 10000 cycles was a sine tapered one. Therefore we calculated the area defined by the hysteresis cycle of the 9950 full range cycle and we called it Absorbed Energy (mJ). Then we plotted these Absorbed Energies in function of the total number of cycles to obtain the behavior of each pad after the three fatigue blocks of 100000 cycles.

3. Results

In table 1 we reported kinematics data referred to 3D pelvic motion during drum tests. For each subject we presented the average among the four trials and then the grand mean among the five subjects.

Table 1. Kinematics data of drum tests.

	Pelvic TILT [deg]			**Delta Pelvic OBLIQUITY [deg]**			**Delta Pelvic ROTATION [deg]**		
Subject	**PAD 1**	**PAD 2**	**PAD 3**	**PAD 1**	**PAD 2**	**PAD 3**	**PAD 1**	**PAD 2**	**PAD 3**
M.F.	24.66	23.03	23.81	6.86	4.51	5.53	2.09	2.48	3.29
V.S.	27.57	26.72	26.85	4.36	7.09	5.65	2.56	1.65	1.77
Z.I.	14.99	18.14	15.34	3.76	5.34	4.90	3.58	5.04	4.46
Z.A.	15.58	14.31	14.90	5.31	4.71	4.43	1.31	1.44	1.37
T.P.	14.33	13.07	15.66	4.29	3.06	4.40	3.99	4.02	3.94
G. Mean	19.43	19.06	19.31	4.92	4.94	4.98	2.70	2.93	2.96
SD	6.21	5.78	5.61	1.22	1.46	0.59	1.09	1.56	1.35

In table 2 data relative to vertical force and pressure of drum tests are presented. Vertical force grand mean was 411.27±47.36 N for pad 1, 395.63±44.65 N for pad 2, 402.68±3.29 N for pad 3. Peak pressure grand mean was 63.43±14.47 kPa, 64.24±12.77 kPa and 66.11±16.40 kPa respectively for pad 1, pad 2 and pad 3. Mean pressure grand mean values were 13.29±1.53 kPa for pad 1, 12.79±1.44 kPa for pad 2 and 13.02±1.11 kPa for pad 3.

Table 3 reported data referred to the potholes. Peak pressure and vertical force values of each subject are the average among all the trials and than a grand mean was calculated.

Table 2. Average data referred to Vertical force, peak and mean pressure of drum tests.

	Vertical force [N]			Peak pressure [kPa]			Mean pressure [kPa]		
Subject	**PAD 1**	**PAD 2**	**PAD 3**	**PAD 1**	**PAD 2**	**PAD 3**	**PAD 1**	**PAD 2**	**PAD 3**
M.F.	335.80	320.69	357.68	41.04	43.09	42.64	10.85	10.37	11.56
V.S.	453.37	428.53	447.22	76.00	77.58	84.42	14.65	13.85	14.46
Z.I.	415.24	388.73	390.25	61.09	66.43	64.12	13.42	12.56	12.61
Z.A.	448.95	416.09	424.25	76.54	68.82	78.64	14.51	13.45	13.71
T.P.	403.02	424.09	393.98	62.46	65.26	60.75	13.03	13.71	12.73
G. Mean	411.27	395.63	402.68	63.43	64.24	66.11	13.29	12.79	13.02
SD	47.36	44.65	34.29	14.47	12.77	16.40	1.53	1.44	1.11

Table 3. Mean values for peak pressure and vertical force during the crossing potholes test.

	PAD 1			PAD 2			PAD 3		
Subject	**P pressure [kPa]**	**V. force [N]**	**V. force [N/BW]**	**P pressure [kPa]**	**V. force [N]**	**V. force [N/BW]**	**P pressure [kPa]**	**V. force [N]**	**V. force [N/BW]**
M.F.	109.2	898.92	1.37	93.87	829.31	1.26	103.47	795.47	1.21
Z.A.	130.93	888.47	1.28	116.53	855.70	1.23	129.07	894.05	1.28
V.S.	116.00	843.56	1.26	124.40	863.11	1.29	117.87	904.92	1.36
G. Mean	118.71	876.99	1.30	111.60	849.38	1.26	116.80	864.81	1.28
SD	11.12	29.41	0.06	15.85	17.76	0.03	12.83	60.30	0.07

Figure 1 showed a comparison for the same three cyclists with the same pad considering the vertical force, the peak pressure and the mean pressure in the two experimental conditions: drum simulator and flat asphalt.

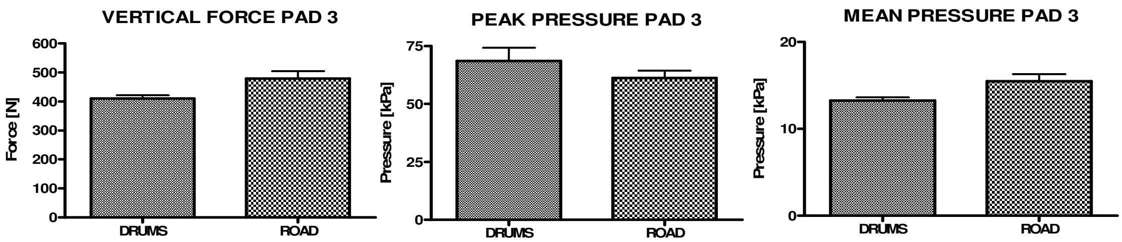

Figure 1. Comparison between road and drum tests for pad 3. Average values are presented.

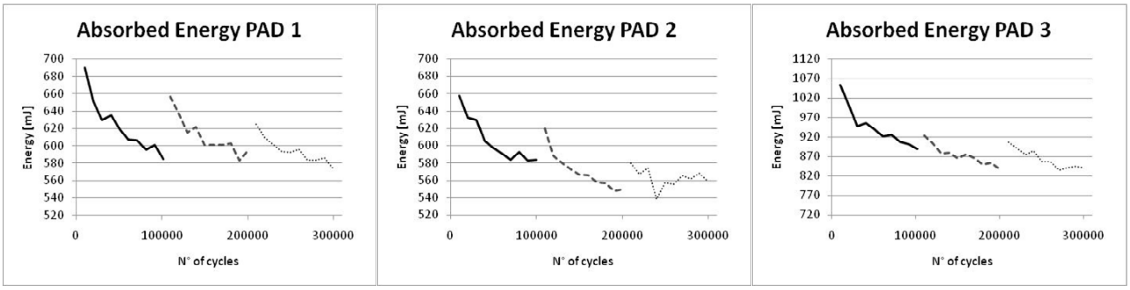

Figure 2. Absorbed Energy of the three pads. The black solid line referred to the first fatigue block, the black dot line to the second fatigue block and the thin dot line to the third fatigue block

Finally results after the 300000 cycles of the fatigue test showed a decrease of the applied energy of 16.86% for pad 1 (from 689.62 mJ to 573.32 mJ), 15.05% for pad 2 (from 657.63 mJ to 558.64 mJ) and 20.19% for pad 3 (from 1054.06 mJ to 841.21 mJ) as reported in figure 2.

4. Discussion and Conclusion

In the present study we developed an integrated protocol to collect data about the pressure cycle acting on the perineal area in different conditions: drum simulator, flat asphalt and potholes. For each condition cyclists performed all the trials with three shorts with three different pads inside. The comparison between drum and road test showed similar values of pressure and vertical force but with higher values in road test (an example is reported in figure 1). This could be explain by the fact that even if cyclists performed all the trials with their own bike, the use of a drum simulator limited the normal oscillations of the bike that instead occurred while pedalling on the road and also allowed the cyclists not to wonder about stability and balance. Maybe these variables changed the weight distribution among seat, handlebar and pedals. Drum tests gave us information about the pelvic motion during pedalling showing that the main movements occurred in the frontal plane and than in the transversal plane, and this was observed with no differences among the three shorts tested. Data referred to potholes showed peak pressure and vertical force values almost twice in magnitude with respect to the same parameters during pedalling on drums or flat asphalt. Therefore other than wearing shorts with padding, it is very important to damp potholes to decrease these traumatic impacts for the perineal area. The fatigue test showed that after 300000 cycles pad 1 and 2 had a similar worsening in absorbing energy while pad 3 had the highest worsening (20.19%). On the other hand pad 3 was the best pad looking at the energy values whereas after the 3 fatigue blocks its energy value was 841.21 mJ against 573.32 mJ for pad 1 and 558.64 mJ for pad 2.

Further investigations are needed to better correlate the cyclists' subjective comfort evaluations with the perineal pressure distribution and the padding material properties and to study the effect of different pads with different saddle design.

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References

[1] Leibovitch I, Mor Y. The vicious cycling: Bicycling related urogenital disorders. Eur Urol 2005; 47: 277-287.
[2] Sommer F, Konig D, Graft C, et al. Impotence and genital numbness in cyclists. Int J Sports Med 2001; 22: 410-3.
[3] Schwarzer U, Wiegand W, Bin-Saleh A, et al. Genital numbness and impotence rate in long distance cyclists. J Urol 1999; 161: 178.
[4] Andersen KV, Bovim G. Impotence and nerve entrapment in long distance amateur cyclists. Acta Neurol Scand 1997; 95: 233-40.
[5] Cherington M. Hazards of bicycling: from handlebars to lightning. Semin Neurol 2000; 20:247-53.
[6] Schwarzer U, Sommer F, Klotz T, et al. Cycling and penile Oxygen pressure: the type of saddle matters. Eur Urol 2002; 41: 139-143.
[7]Jeong SJ, Park K, Moon JD, et al. Bicycle saddle shape affects penile blood flow. Int J Impot Res 2002; 14: 513-7.
[8] Cohen JD, Gross MT. Effect of bicycle racing saddle design on transcutaneous penile oxygen pressure. J Sports Med Phys Fitness 2005; 45: 409-18.