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Original Article

Outdoor activity: orienteering, one step towards an advanced scientific evaluation of game determinants using latest dedicated technologies combined with literature review

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Abstract
The purpose of the researches of the ARGS group (Advanced Research Group in Sport) is to try to create specific scientific work parameters obtained with objective means, to better qualify and quantify the performance descriptors of orienteering, in this case, to better define the physiological model, an essential element to outline the real needs for a safe and performative practice,for all types of participants.It would be a mistake, in our opinion, to evaluate orienteering as a recreational activity, simple and free of risks for individual health since it is a competitive game substantially based on speed and its components such as accelerations, decelerations, changes in run speed, and direction. Moreover, the cognitive commitment is crucial, such as those deriving from the reading and analysis of topographic maps to find the points defined as "lanterns" and thus reach the finish line in the shortest possible time.However, a sport that, although nominally known by everyone, is often considered just a walk over the mountains or a recreational treasure hunt, with all the benefits that these activities still bring with them, but therefore not considered with those values that are instead in is own and that certainly insert it as a real motor-sport activity with an important additional element in addition to the location (usually the natural environment), that is the not excessive competitive charge. This investigation analysis has, in the end, the aim to define a proper way to identify the physiological and physical request of the sport and to the extent the application of advanced technology to orienteering and evaluate the possible benefits of using them. The expected result is, therefore, to elaborate parameters on the real consistency of the external load in relation to the internal one caused by orienteering, which can then be applied in its various modalities and different individuals, helping them to avoid traumas and injures too, using the latest generation of wearable devices and therefore without creating discomfort.
Keywords: Orienteering, sensorized shirt, inertial sensors, GPS, specific parameters

Introduction

The purpose of the research of our group (ARGS, Advanced Research Group in Sport) is to establish specific parameters obtained with objective means and methodology (latest dedicated technologies), to better qualify and quantify the performance descriptors of sports, in the case of orienteering, in order to better characterize the physiological model of the activity, that is an essential element to define the real needs for the safe and performative practice, for all different modalitiesof this sport and participants types.Evaluate orienteering as a recreational activity, simple and without risks for health it's a mistake, since, it's a competitive game substantially based on speed and its components such as average speed, accelerations, decelerations, changes in speed and direction and measuring energy costs as well as cognitive elements such as those deriving from the reading and analysis of geographic maps (in a very short time), with the purpose to find the points defined "lanterns" and thus reach the finish line in the shortest possible time(Di Domenicoet al., 2019a,b, D'Elia et al., 2020).

This also with the aim to define an activity that over the years has tried several times to qualify as an Olympic sport without success a well-defined activity both in the physiological and biomechanical area. However, a sport that although nominally known by everyone is often commonly considered as a walk over the mountains or a recreational treasure hunt, with all the benefits that these activities bring with them. In our view, it is therefore not considered with those values that are instead intrinsic to the activity and that certainly define it as a real motor-sport activity with an important additional element, that is the not excessive competitiveness (Raiola et al., 2013, 2017). The aim of this paper is to establish how and to what extent the application of advanced technology tools to orienteering, with the goal to derive physiological, biomechanical, and physical

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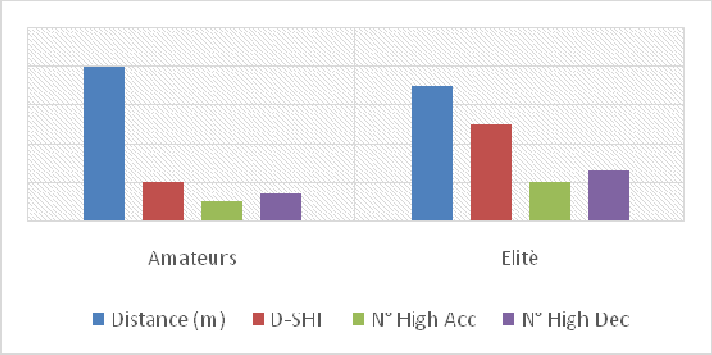
data, not yet present with this intent in the sport-specific scientific literature, and to describe the benefits, that those can bring to the practitioners as well as the professional athletes.Conceptually the work we would like to attempt is to elaborate parameters concerning the external load in relation to the internal one. Through which it will be possible to analyze not only the tracking path related to the movement (D'Isanto et al., 2019a,b),[1] but also,even more of what above mentioned, to analyze the speed thresholds, the symmetry of running, the energy expenditure, and also, an element of absolute innovation, the measurement of cardiac activity, through an electrocardiograph in textile material, with high static precisionand a sensor for the detection of respiratory rates(Altavilla et al., 2017, 2020)[2]. In essence, the different possibilities of orienteering will lead to a calibration of the parameters to be detected in their specificfunctions and help to establish the performance model for every cited type of athlete category (D'Isanto et al., 2017). As it's possible to see in Graph 1, for example, amateurs will cover high distance (meters) than elité probably due to the difference's physical performance and cognitive abilities, otherwise,elité will produce higher values in high intensity distance, acceleration, deceleration and numbers of bouts.



Graph 1:Hypotheticalorienteers performance model in comparison between elitèand amateurs'athletes.

Orienteering was born in 1919 when the first official orienteering competition was organized near Stockholm, in which 202 competitors took part (Anthony, 1982, Boga, 1997). In the twenties there was a rapid increase in participation, the first international competition was held in 1932 between Sweden and Norway(Renfrew, 1996). The founding of the International Orienteering Federation (IOF) in May 1959 in Sweden made a significant contribution to the development of orienteering.Over the years numerous scientific researches have been produced on the subject, from 1978 to 2020, about 200, starting from the studies ofHoppeler (et al, 1973) where the structure of skeletal musclesof Orienteers wasanalyzed, comparing athletes of high and low level, also differentiating their gender. Barrell (et al. 1982) defines the somatotype characteristics of the orienteering athlete, and thanks to the studies of Gershon (et al., 1986) the foundations for research on the strong cognitive component of this sport are laid. Bird (et al., 1993) analyze the internal load of orienteers by heart rate evaluation, the results showed that all subjects recorded heart rates that were between 140 and 180 beats min^{-1}, data indicated that the activity was largely aerobic but varied in intensity, with phases of strenuous anaerobic work. In 1997 two studies, one by Rolf (et al.) and the other by Creagh (et al.), analyzed the ability to work in an aerobic and anaerobic regime, the muscular characteristics of the lower limbs in elite level athletes and assessed, even if superficially the biomechanical component. Larsson (et al, 2001, 2002) analyzed the performance of orienteering for the first time by comparing laboratory and field tests, using GPS detection systems and metabolimeter. The findings were that a correlation analysis showed a relationship between a high anaerobic threshold and a few orienteering mistakes during the race ($r = - 0.64$, $P < 0.05$). Furthermore, they can be seen as high threshold levels, which can be related to faster execution and high running speeds, these were the best indicators of the best performance.

In 2003(Smekal et al.) were analyzed the respiratory gas exchange and lactate measures during competitive orienteering race, the finding was that the energy requirements the competitions were derived predominately via aerobic metabolism, the highest VO2Max value detected were of 64.4 mL.kg-1.min-1,also using only the lactate for evaluation may lead to overestimation of energy demands. Guillaume (et al., 2010) examined changes in the running pattern due to fatigue and cognitive load during the race, the effects of fatigue on running biomechanics depended on whether the orienteers read their map or run normally,the conclusion was that adding a cognitive load does not modify running patterns. Therefore, all changes in the running pattern observed during the orienteering simulation, particularly in elite orienteers, are the result of adaptations to enable efficient map reading and/or potentially prevent injuries. Finally, running patterns are not affected to the same extent by fatigue when a map-reading task is added. In 2014, Hébert (et al.) analyzed jumping and hopping in order to measure lower-body muscle power, stiffness, and stretch-shortening-cycle in orienteering. The findings were that overall, the elites exhibited superior stretch-shortening-cycle utilization and rapid generation of high relative maximal forces, especially vertical ones. These functional measures were more closely related to sprinting and/or running abilities, indicating benefits of lower-body training in orienteering. Again Hébert (et al.,

2014) tried to compare the reduction in running velocities from the road to off-road terrain in eight elite and eight amateur male orienteer athletes. The elite orienteer ran faster than the amateur on all two surfaces, in line with their better running economy and aerobic power.The scientific evidence on the traumatology of orienteering relates to the studies by Foss (et al. 2012) and Halvarsson (et al., 2018), in which the presence of numerous low back pain, knee joint problems, and ankles are highlighted. In recent years, numerous studies have been carried out on cognitive characteristics, visual search characteristics, precise map reading, and visual reaction, those are crucial elements for the developing orienteers (Pulur et al. 2017, Robazza et al. 2018, Liu 2019, Pulur et al. 2020).The performance model of orienteers is multifactorial, because this is a sport in which both endurance fitness and mental skills are needed to achieve performance, more in specific are requested high levels of aerobic fitness and anaerobic power, comparable to those of middle-distance track athletes; on the other side, attentional, decisional and problem-solving skills are essential (Kolb et al., 1987, Eccles et al. 2002a, Galan et al., 2019).

The role of cognition and attention is crucial in orienteering, athletes need to maintain focus to execute accurate planningstrategies and at the same time perform a physical effort. An orienteer during a race needs to manage attention to three sources of information: the map, the environment, and the path (Eccles et al. 2002b). For an orienteer, it is critical to select relevant map information and compare it with the information from the surrounding environment, this is performed frequently switched from a narrow focus of attention to the map (zooming in) to a wide focus of attention to the environment (zooming out) are needed (Pesce at al. 2007, Sirakov et al., 2018).Orienteering can be practiced at a competitive or amateur level, even in older age, the age-related decline of the ability to perform visual attentional focusing might represent an important problem faced by old orienteers, in the otherhand the practice of this sport may counteract or offset the age-related decline of attentional performance with the high physical-aerobic training and extensive experience with tasks that have high cognitive-attentional demands (Kramer et al., 1999, Roth et al., 2003, Blagii et al., 2018, Vaskan et al., 2019).

Project

Our study and analysisproject on orienteering wants to highlight realistic parameters and descriptive elements, from which startingthe research project in order to establish game determinants, that are those that in our point of view will constitute the functional reference model of performance in orienteering. The orienteering performance model is multifactorial and is based essentially on two macro areas: quality of endurance, more specifically high level of aerobic and anaerobic capacity and mental skills such as the ability to solve problems in a short time and attentiveness and mental focus, properly connected to execute an accurate strategicplan.There are three key elements in the orienteer's attention focus: the map, the environment, and the itinerary (Eccles et al., 2002a,b). In order to adequately perform, an orienteer needs to select crucial information from the map and simultaneouslyadapt it to the surrounding environment.Following a careful analysis and having fully established the state of the art of the reference scientific literature, is clear how there is a lack of analysis of external and internal load in the orienteering discipline. This lack is found hand in hand both in the evaluation of the competitions and in the preparation training for them, this can cause inaccuracies and difficulties in the design and programming of the units and training cycles. The use of hardware and software in sports in the last decade had exponential growth, starting from the evaluation of the internal load through analyses carried out with the last generation ofGPS, IMUand Video Tracking in the world of team sports, evolving and expanding also to individual sports of a competitive and amateur nature (Izzo et al., 2018a, 2018b, 2019a). The implementation of GPS technology has undergone considerable development, passing from devices with detection capabilities at 1 Hz, and then moving over the years to models at 5, 10, 15 and 20Hz.

Table 1: Comparison between different GPS Hz frequency (Johnston, et al., 2014)

GPS TYPE	Total Distance	Max Velocity Peak	Velocity > 20 Km/h	Metabolic Power (>25 W/Kg)
1 e 5 Hz	<7,2 %	10%	17 – 30 %	7 – 23 %
10 Hz	1 - 1,9 %	1,60%	0,8 – 19,9 %	4 – 10 %
15 Hz	2%	< 1%	/	/

Until the recent realization of the 50 Hz models (2018, K-50, K-Sport Universal, Italy), with the inclusion of inertial sensors and a firmware containing a powerful mathematical calculation program which then led to insertion, in the last two years, of artificial intelligence (K-AI, K-Sport Universal, Italy) which have allowed an important and extremely precise review of most of the previous motor-data parameters, which were inflicted with large derivation error (Hosseini et al., 2020).

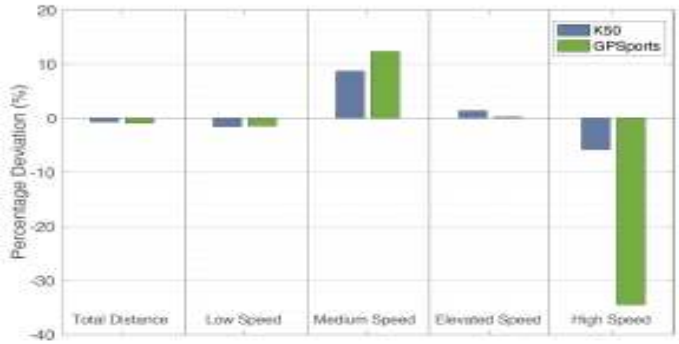
It should be noted that the evolutionary progression of the data detection frequencies in the instruments means an increase in the quality of the detections themselves which in the latest releases reach an accuracy of almost one hundred percent, although sometimes the increase in the sampling frequency requires filtering of the engineering type, that greatly complicate the reading of the technicians from the different sports and motor

activities (Izzo R., 2020). The algorithm necessary to compare quantitative and qualitative data (Fig. 2) was builtfor football actions (K-Sport Universal) but could be modified to be use in orienteering:

$$C_n = a' \times f'(A_n) + b' \times g'(T_n^{Volo}) + c' \times h'(D_n^{Pass}) + d' l(D_n^{Tr-anv}, X1) \times e' m'(D_n^{Tr-Com}, X2)$$

Fig. 2:Equation (K-Sport Universal).

Following our previous studies, this paper aims to propose a more complete and precise theoretical model of orienteering performance, designed to define those real values necessary for correct programming of the training session for performative purposes, in the sense of the best personal performance without particular references to the pure competitive work of elite athletes (Izzo et al., 2019b). In support of the importance of technological innovation follows the purchase graph between the latest generation devices (Graph 2).



Graph 2: Comparison between K-50 and common GPS for Sport.

Given the availability of new generation hardware, being the detection capacity of the K-50, without a high margin of error, able to reduce to a minimum data collecting disturbances. The hardware features are as follows, GPS with 50 Hz sampling frequency, 4000 Hz IMU, the capacity of transmission of raw data in real-time to the computer using a wireless antenna that can manage 25 devices and 25.000 data per second in real-time.

Materials and Method

The aim of the project is to establish a proper detection methodology of external load and internal load[3,4] for orienteers, both in training and competition, to build a proper training plan and prevent overtraining syndrome, injuries,and cognitive stress. The definition of the internal load is represented by the amount of stress that the organismundergoes in relation to an external load. The external loadis the objective quantification of the means used in training such us total distance, numbers of accelerations and decelerations, etc.. The hardware used to perform our project will be the K-Shirt that include features as follows, K-AI GPS, with 50 Hz sampling frequency, 4000 Hz IMU, heart rate and ECG monitor and the capacity of transmission of raw data in real-time to the computer using a wireless antenna that can manage 25.000 data per second in real-time(K-Shirt; K-Sport Universal, Italy)[5,6].

The project aims to evaluate internal load using:

- Edwards: based on five heart rate zones50-60%; 60-70%; 70-80%; 80-90% and 90-100% of Hrmax (Impellizzeri et al., 2004);
- Borg CR-10 RPE Rate of Perceived Exertion and SRPE; Session RPE is a qualitative-quantitative method used to measure the internal load through the numerical scale modified Borg CR10 (Impellizzeri et al., 2004).

External load using:

- **TD** (m): Total distance;
- **EEE**(Kj/Kg):Energy Expenditure;
- **D_SHI**(m): Speed High Intensity Distance >16 Km/h;
- **D_AccHI**(m): Acceleration High Intensity Distance > 2 m/s²;
- **D_DecHI**(m): Deceleration High Intensity Distance < -2 m/s²;
- **D_MPHI**(m): Metabolic Power High Intensity >20W/Kg;
- **D-A1**(m): Very High Intensity Deceleration Distance < - 3m/s²;
- **D-A8**(m): Very High Intensity Acceleration Distance > 3m/s²;
- **D-S5**(m): Very High Intensity Distance >20Km/h.

Another crucial evaluation can be the analysis of asymmetry of walk and run(Izzo et al., 2019b), to detect this data, we use the IMU sensors from the K-Shirt, the evaluate parameters will be:

- **Training Load**: this parameter expresses the total workload developed, it is calculated in [G];
- **Average Strength**: this parameter observed instead in parallel with the training load, provides an indication distribution average of strength during training, it is calculated in Newton [N];
- **Lateral imbalance (left and right)**: this parameter provides general information on symmetry and postural performance;
- **Number of vertical jumps**: it indicates the number of movements made upwards, then the actual number of vertical jumps;
- **Vertical jump accelerations (intensity)**: related to the previous parameter it provides instead information on the intensity with which it is every single movement was expressed (m/s^2).

Results

An instrumental analysis of the determining elements of the disciplines it is believed will lead to a more adequate and correct architecture of the training sessions. Especially the calculation of energy costabove technical elements is considered very useful for a calibration of the requests in the proportions of training exercises.The mission is, some in many other studies of this kind, to start the training methodology on tracks imposed by objective analysis and not only based on the experience of the technical staff.

Discussion

The aim is to analyze the energy cost involved in orienteering, taking into account the accelerations and decelerations at high and very high intensity and to give scientific value to the running speed and its many variations. The parameters want to help establish and differentiate with a work that is in any case optimized, performance models for both the elite and amateurs and for further different types of participants, including also adult and elderly athletes or participants with disabilities. To better understand this, the different running intensities and their variants in the correlation between the various categories will be evaluated thanks to the aforementioned instruments. Another element that seems to us to be very important and certainly useful will be that of verifying the traumatological dangers created by the practice of orienteering, according to the data obtained, given the evidence found in the literature cited above from which they can be deduced (Foss, et al. 2012, Halvarsson, et al. 2018) numerous injury problems including low back pain and lower limb joint strain. The performance model will include the definition of a set of the main parameters to be taken into due consideration such as the total distance, average speed, distance at high speed, distances and number of accelerations and decelerations qualified in the various categories of intensity, of the individual load per athlete. Also available for research is the latest generation of tools which also include the K-AI Wearable Tech, which has enriched the K-50 and which, using the latest generation of computerized textile material, allows for the ECG in real-time and with a precision identical to a hospital electrocardiograph, which will allow us to detect data, now not present in the literature such as heart rate, heart rate variability, and heart rate fitness zones as a function of individual HRmax.The proposed project is of a methodological type, the authors set themselves the goal, that of being able to apply it to a necessary number of athletes in order to be able to propose to the scientific community and orienteering coaches and athletes, an objective model for the construction and evaluation of the performance both in competition and in training, with the final aim to create a functional model not only for the elitè but for all types of subjects who participate (Altavilla et al., 2018, 2019a,b, Di Domenico et al., 2020)[7].

Author Contributions:

Conceptualization: Izzo R.
Methodology: Izzo R., Cejudo A., Hosseini C., Giovannelli M.
Validation: Izzo R., Giovannelli M.
Formalanalysis: Hosseini C., Giovannelli M.
Investigation: Cejudo A., Giovannelli M.
Resources: Giovannelli M., Hosseini C.
Data curation: Izzo R., Cejudo A., Hosseini C.
Writing, original draft preparation: Izzo R., Cejudo A., Giovannelli M.
Writing, review and editing: Izzo R., Hosseini C., Cejudo A.
All authors have read and agreed to the published version of the manuscript.

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