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# FORCE AND CENTER OF PRESSURE EVALUATION WITH AN INSTRUMENTED PLATFORM FOR SWIMMING PERFORMANCE OPTIMIZATION

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Start technique may consume an important amount of time in swimming events. Its optimization is the main target of a force platform design and implementation in order to bring benefits to coaching and to swimmer's performance. Such a platform is being designed for technical performance evaluation of the start technique in elite swimmers and mimics the start block, namely fulfilling new FINA's facilities rules. The purpose of this study is to present results of calibration procedures in order to define transfer function for determination and measurement of force and centre of pressure position in such an instrumented platform.

**KEY WORDS:** strain-gauge, repeatability, load cell.

**INTRODUCTION:** The swimming performance is significantly conditioned by its start phase (Cossor 2001, Vilas-Boas 2003, Nomura 2010) as the total event time is distributed along three unequal phases, particularly: (i) the start time (0.8% to 26% of total elapsed time (Cossor 2001), depending on event length), (ii) swimming time and (iii) turning time. The start time phase can be considered as the instant just before the beginning of the swimming motion, and is usually subdivided in block time and impulse, flight, water entrance and glide, leg kicking and full swimming to the 15m mark. Meanwhile, Féderation Internationale de Natation (FINA) facilities rules recently adopted innovation in the starting platform assembly including an adjustable back plate, being its effect object of study (Nomura 2010).
Force is a physical essential parameter which measurement can be carried out with a handful of devices. Its quantification is also a useful parameter in the evaluation of efficiency in sports practice in general and in swimming in particular. Data force is a valuable tool to help measure and interpret the total time in phase (i) (Vilas-Boas 2003) and, also, as it can be associated to impulse measurement and can lead, providing mass knowledge of the swimmer, to velocity changes while in block contact. The other subdivisions of start time seem to be constrained, in consequence, by this very beginning phase.
With these premises in mind, it is perfectly justified the implementation and development of a platform for force measurement that mimics a normal start block defined by FINA including back plate as well as lateral and frontal instrumented handgrips.
The purpose of this study is to establish the determination of force and position of the centre of pressure using such platform.

**METHODS:** A first prototype of load cell was conceived according to geometry proposed in Figure 1. This configuration was selected because it combines simplicity with versatility and allows an easy instrumentation.
The development of the load cell included judiciously chosen loci for strain gauge sensors in order to distinguish or disambiguate total force from total momentum applied.
A calibration procedure took place for strain measurement collection in order to build sensor response function to different forces. For effort minimization and speed up operation, a setup was assembled with a lifting bridge using force multiply sheaves (Figure 2 left).


**Figure 1: Load Cell Design and prototype and schematic presentation of the loci chosen for strain gauges**

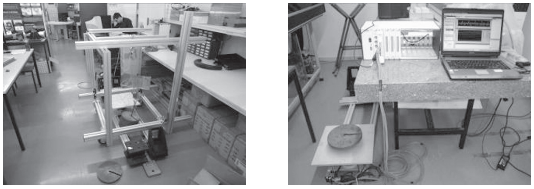

**Figure 2: Setup for weight lifting and for calibration purposes.**

Twenty-one force application points were chosen and distributed in a suitable pattern used for mapping response to force application. Values of force and loci were registered as well as strain response set using a data acquisition board (Figure 2 right).
The experimental setup includes a platform physical apparatus with strain gages HBM, 350 Ω, and National Instruments NI SCXI-1001 data acquisition system with NI 1520 and NI 1314 modulus for strain measurements with a sampling rate of 1000 Hz and 4 synchronous channels with ¼ Wheatstone bridge configurations for each strain-gage measurement. Data acquisition is completed with National Instruments LabVIEW™.for datalogging and with.MatLab® (MathWorks™) suitable routine for later data processing.

**RESULTS:** After a calibration procedure the solution adopted for the device exhibited an excess rigidity implying low signal/noise ratio. Besides, applying increasing load at the device, deformation of the support structures disturbed the load cell response function. Another load cell with the same topology was built for lower loads. Data acquired from this device was used for an evaluation of total force applied and centre of pressure position. Figure 3 shows the load point scheme and the signal acquisition. Figure 3 (right) exhibits the output of the device when a force of 9.8 N is applied where numeric labels respect the raster scheme of Figure 3 left which is parallel to positions of strain-gauges #2 to #1 segment of Figure 1 (right). Figure 3 (left) shows the signal symmetry of the opposed strain-gages #1 and #2 in respect to the twin baseline generated by #3 and #4. Also, this baseline is a linear function of the force applied as can be observed in Figure 4, where force was applied at the centre of the load cell.

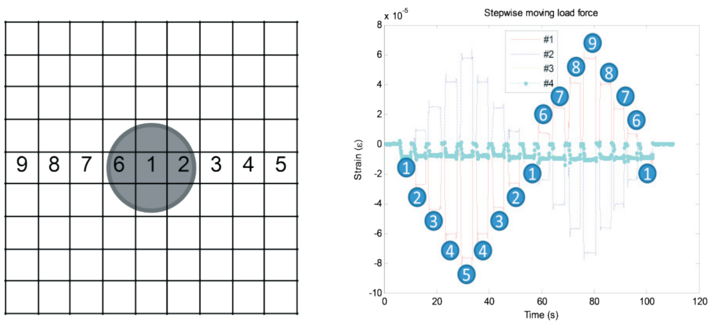


**Figure 3: Scheme adopted for a stepwise moving constant weight applied to the load cell (left). 4 channel simultaneous strain (ε) measurement function of a stepwise moving weight applied**

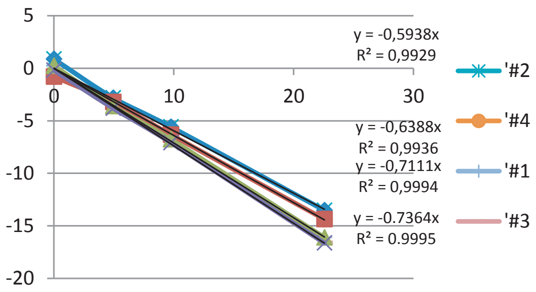


**Figure 4: Four channel simultaneous strain (με) measurement function of a increasing Force applied in position 1.**

It is possible, therefore, to disambiguate force from momentum implying that the application point of the force can be identified. Mean of strain measurement of 4 channels is proportional to Force and subtraction of opposition channels is proportional to Momentum applied leading to the assessment of the centre of pressure.
Further study showed that relative repeatability in force measurement is in the neighbourhood of 10% with 95% confidence. The Force application point, measured to centre, has been determined to be with the same repeatability. This topology is sufficient to determine all Force components, and can measure the x and y Momentum components but lacks Momentum z-component (some more strain-gages are to be added in the future for this purpose).

**CONCLUSIONS:** This study presented a load cell which will be included in a platform for optimization of the starting technique of swimmers. This device should evaluate force and momentum for a 3D characterization of block time impulse. As force and momentum magnitude are believed to determine starting proficiency, it is relevant their measurement. The platform already measures variables related to force and momentum, leading these values to the assessment of the centre of pressure position. Repeatability in measurements has been found to remain inside 10% neighbourhood of measurand.

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