INTERNATIONAL SEMINAR

OF ARTISTIC ROLLER SKATING

ROCCARASO 2010

KINEMATIC ANALYSIS OF FIGURE EXERCISES

IN ARTISTIC ROLLER SKATING

by Prof. Franco Merni, Silvia Fantozzi, Micaela Orlandi of the University of Bologna, by F.I.H.P. Coaches Antonio Merlo, Raffaello Melossi e Piero Trentini

S.I.P.A.R. Scuola Italiana Pattinaggio Artistico a Rotelle

Kinematic analysis of figure exercises in artistic roller-skating

Faculty of Exercise and Sport Sciences, University of Bologna, Italy

Merni Franco, Professor of Theory and Methodology of Training and Motor Evaluation **Fantozzi Silvia**, Lecturer in Applied Biomechanics and Bioengineering **Orlandi Micaela**, BSc in Sports Sciences

This study has been realized thanks to the jointwork with the Hockey and Skating Italian Federation. Special contribution by Antonio Merlo, Raffaello Melossi, Piero Trentini, Sara Locandro.

A special thanks to the athletes, who have offered for this study: Dario Betti, Elis Carriero, Candida Cocchi, Giulia Fornai, Silvia Lambruschi, Federica Nannetti, Andrea Poli, Marco Santucci, Ginevra Ventura.

Introduction

Figure exercises (FE) are key exercises in artistic roller-skating, and thus they are introductory to all other more complex exercises. Therefore, carrying out movement analysis studies on (FE) is very important. The results of these research will in fact provide very thorough information about the skate movement, the supporting leg, the free leg and the trunk.

The only available data on (FE) come from a essay of the Italian Federation (Merlo 2008). In that essay, the movement is explained using a qualitative approach, and the wheel displacements are analysed through signs left by the skate on the chalk. Among the many (FE) described in the essay, we decided to consider in this study the

- **Forward outside bracket (FOB)**, consisting in a turn performed on one foot with a change of pressure and a clockwise or counter-clockwise body rotation in a sense opposite to that of the movement. The exercise is executed in correspondence of the longitudinal axis of the circles; it has the length of one skate and the depth of one skate's truck.
- **Backward inside bracket (BIB),** following the same principles of the FOB, but with a backwards execution.
- **Forward outside counter (FOC),** consisting in one-foot turn from one circle to another, without a change of pressure and with a body rotation that is opposite to the initial direction of the movement. The exercise is executed on the longitudinal axis of the circles, in their tangency point. It must have the initial length of one skate and a depth between the length of one truck and one-half the length of one skate.
- **Backward outside counter (BOC),** following the principles of the FOC, but with a backwards execution.

Then, in the brackets a change of pressure is executed during the skate's rotation, whereas in the outside counters the initial pressure is maintained.

Quantitative biomechanical assessments on (FE), even in ice skating, have never been performed. Therefore, this is the first research carried out on this discipline.

The first aim of this study is to describe the skate's wheels trajectories during the four above (FE) by observing the precision of movements in the two axes of the plane (advance/delay and depth).

The second aim concerns the analysis of the athlete's body segments movements, considering the support leg, the free leg and the trunk.

The last purpose is to assess the differences between the four considered exercises and the movements sequences by which they are characterized.

Subjects

Eight world-class skaters, representing the best European and world athletes, were involved in the study. In their training schedule, a considerable amount of time was dedicated to (FE). The mean anthropometric, performance and training data of the subjects are reported in the following table.

	Age	Height (cm)	Body mass (kg)	Training hours per week	Figure exercises hours per week
Mean M	19.5	175.0	65.3	18.3	12.0
Mean F	17.2	164.0	54.7	16.6	13.4
Mean	17.9	167.1	58.2	17.3	12.9
Min	14.0	160.0	50.1	6.0	6.0
Max	24.0	177.0	72.6	35.0	25.0
St. Dev.	3.4	6.4	7.9	9.7	6.9

Equipment

A motion analysis system constituted by ten synchronized cameras was used.
The system allows a computerized reconstruction of the position of apposite markers placed on the athlete's body and on the skate. Therefore, three-dimensional spatial assessments can be performed. The BTS SMART-D Motion Capture System is an optoelectronic system allowing the study of the human movement through the measurement of indices such as position, speed and acceleration, that describes the kinematics of body segments.
The hardware component is constituted by a kit of reflective markers and a set of ten infrared cameras. The markers, reflecting the light of infrared lamps, are plastic spheres of different dimension. They are covered with a reflective material and can be applied directly on the body or the skate with a double-sided tape or elastic bands.
The cameras have a maximum resolution of 0.48 Megapixel with an acquisition rate of 250 photograms per second. The ten cameras were placed around the tangency point of the athlete's trajectories at various heights to film the markers from different points of view: some of them were higher than the subjects, whereas others were at very low heights.
The software component of the system is constituted by the Smart Capture, through which the calibration and the image acquisition are performed. Furthermore, the Smart Tracker is the software allowing to individuate the markers coordinates and analyse their trajectories. Finally, the data are analysed through the Smart Analyser, a protocol that computes all the derived measures as distances, axes, and angles, and allows to visualize the relative graphs.

The markers corresponding to the skate's wheels were placed on the axes. Therefore, they did not correspond to the wheel's centre, but were placed 25 mm outside.
The Analyzer Software of the BTS system allowed to produce spatial diagrams and graphs of speed as a function of time. Furthermore, the coordinate values of the wheels were exported to Microsoft Excel for an analysis of the various phases of the skate's rotation.

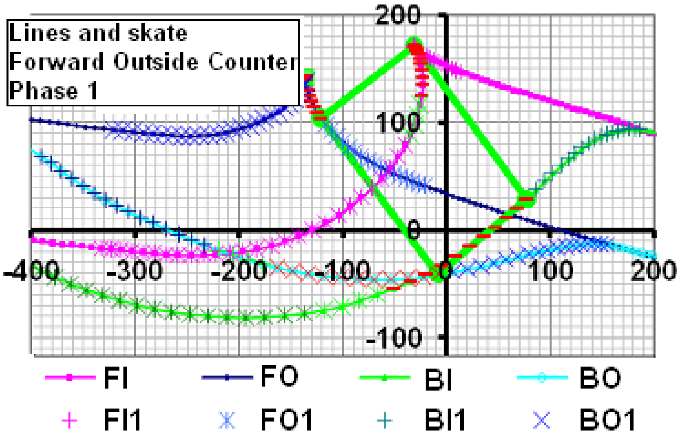
Results

Individuation of the skate rotation phases

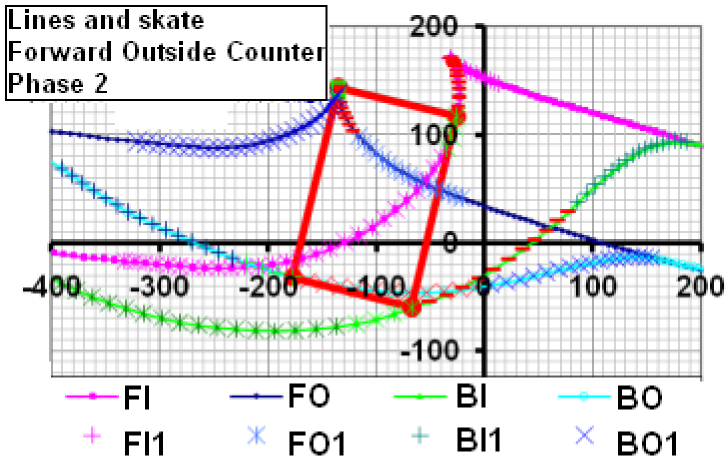
The wheel's velocities with respect to the x-axis (in the direction of the movement) and with respect to the z-axis (corresponding to the depth action) were used for this analysis. The wheels presenting moments with speed equal to zero in the speeds graph, are identified as pivot wheels. The wheels speed diagram first goes to zero, then it displays very low speeds in the opposite direction.
The movements in the opposite direction occur with different timings: in the two forwards exercises, the wheel decelerating first is the front inner one. The inner wheel, after a first zero speed point, turns back with respect to the direction of the main movement. Then, it shows again a zero speed in correspondence to the moment in which the outside wheel is blocked. The point in which the two wheels are blocked was identified as "coincidence phase". In this phase, the outside wheel is completely blocked, as it shows a zero speed also in the z-axis direction.
Concerning the backwards exercises, in the BIB, the wheel stopping first is the back outside one. On the contrary, in the BOC, the back inner wheel stops first. The wheels behavior during the skate's rotation is the same than in forward exercises. Observing the vertical (y-axis) wheels displacements, two cases out of all four exercises were individuated in which a lift of the wheel occurs. In the first case, an ahtlete in all the 3 trials of the FOB, lifts up the back outside wheel by from 2.0 to 3.5 mm. In the second case, another athlete in all the 3 trials of the BOC lifts up the front inner wheel from 2.5 to 7 mm.

For a further analysis of the wheels trajectories, the coordinates of the correspondent markers were exported to Microsoft Excel. Thus, easily constructible and readable graphs in the two dimensions corresponding to the ground have been obtained. Different colours were used to define the front inner wheel (FI), the front outside wheel (FO), the back inner wheel (BI), and the back outside wheel (BO). The phases of the rotation have been pointed out with different colours.

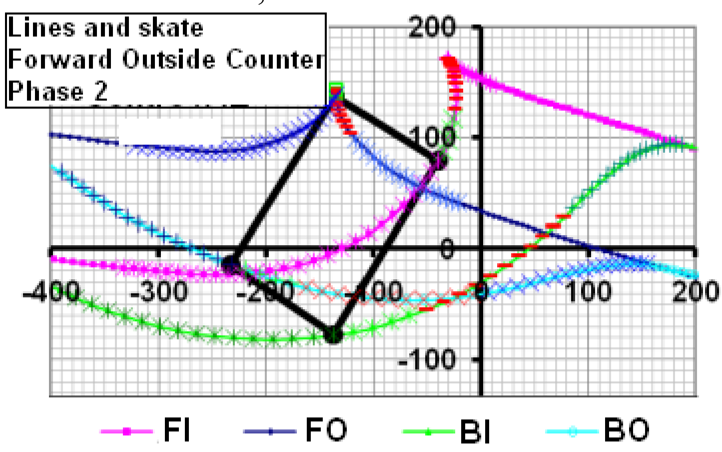
-Phase 1, corresponding to the braking action of FI and the acceleration of FO, at this point the back wheels also exit from the trace;



-Phase 2, whereas FO decelerates, FI reverses the direction of the movement on both the axes;

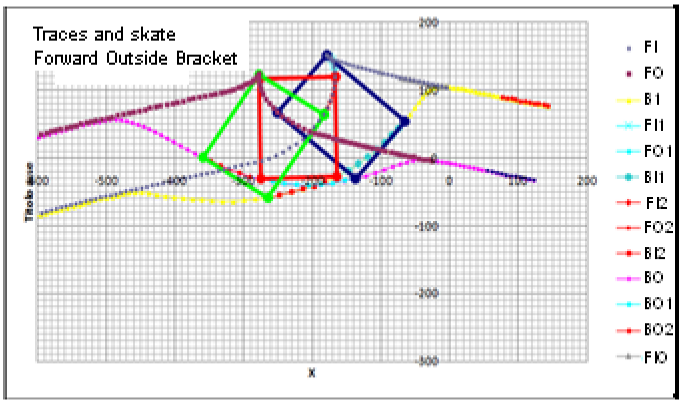


-Phase 3, FO is blocked (pivot action), whereas FI restarts its motion in the direction of the movement;



-Phase 4, FO accelerates in the direction of the movement and, together with the other three wheels, it regains the trace.

In the figure, three positions of the skate corresponding to the beginning of the second phase and to the two following phases, were highlighted. It is evident that at the beginning of the second phase, the FI wheel reaches the highest depth. In the third phase, the FO wheel reaches its highest depth, that is inferior to that reached by FI in the previous phase, but it is higher of that shown by FI at the end of the third phase.



The zero speeds of the two forward wheels were considered as a reference time point to individuate the beginning of the second and the third phases. In fact, these points represent exact and constant events in all the four exercises for all the examined subjects.

Temporal data

In order to determine the duration of the pivot phases of the skate, the zero-speed points were considered. The duration of each phase was computed by assessing the number of photograms between the events that identify that given phase.

It comes out that the BOC showed the shortest duration of the pivot phase of the first wheel. The longest duration is instead observed in the BIB. In the FOB, the shortest duration of the second pivot wheel is noticed, whereas the longest one is observed in the BIB. The FOC and BOC show the same duration of pivot phase of the second wheel.

In all the exercises, the first wheel pivot phase is longer compared to the same phase of the second wheel. Furthermore, about the durations it can be noticed that in BIB the two pivot wheels work for a longer time compared to the correspondent phase of the other exercises.

In the counters, the durations of the pivot phases of the wheels are shorter than in the brackets. This emphasizes that in the counters the skate's movement is faster than in the brackets.

Spatial data

The precision of the examined movements was assessed considering the distances of the wheels from the axis in the direction of the movement (x-axis) and in the depth (z-axis). In this last case, the distance of the wheels in the point at which the skate is perpendicular to the axis (neutral point) was considered. The diagram displaying the precision of the exercises with respect to the reference axis shows that the athletes tend to move beyond the reference axis with the first pivot wheel.
The counters are the exercises with the highest precision on the x-axis. On the contrary, the BIB shows the highest mean error. Therefore, we can state that the BIB is the most difficult exercise concerning the precision. In the BIB, the wheels reach the smallest space in the in-depth precision. Conversely, in the FOB the wider lateral space is reached by the two pivot wheels.

Hip angles of the free leg on the sagittal and frontal planes

The hip flexion angle at the beginning and at the end of the skate rotation was assessed, considering the axis connecting the anterior and posterior iliac crests of the free leg with respect to the thigh axis (anterior iliac spine and midpoint between epicondyles).

The hip abduction angle has been assessed considering the axis between the two anterior iliac crests and the thigh axis at the midpoint between the epicondyles.

The maximum and the minimum values of the hip angle were considered. Furthermore, for the FOB and the FOC, a relative abduction peak occurring between the two indicated points was measured.
On the whole, at the beginning of the rotation the hip is more extended than at the end of the rotation. Only in the BOC an opposite situation occurs, i.e. with an initial flexion and a final extension, as BOC is the only exercise performed with the leg forward. Concerning the movements of the free leg on the frontal plane, the athletes use different strategies in the exercises performed backwards compared to those performed forwards. In the two backwards exercises, the hip is more adducted both at the beginning and the end of the movement (63°-65° initial and 71°-72° final vs. 83°-84° initial and 80° final). In the forwards exercises the adduction angle is less marked (84° vs. 64°).
In the central phase of the movement, the athletes perform an abduction hip action leading the thigh axis near the neutral position (corresponding to 90°). Then, a hip adduction is executed at the end of the rotation. The angular values of each phase in the two exercises are very similar, with a maximum difference of 1°.

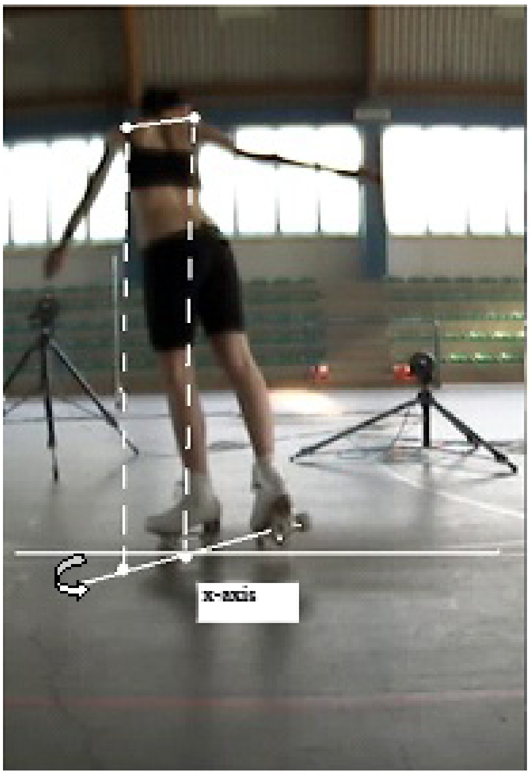
Trunk axis angles

The trunk was individuated considering as reference points: the midpoint between the two acromions, the midpoint between the two iliac crests, and the midpoint between the lines connecting the four iliac spines.

In the graph of trunk positions, the mean angular values were identified in three points: the initial trunk flexion, the flexion peak, the trunk flexion in the final phase of the skate's rotation. Only three exercises were examined as in the BOC there were many missing data.
In the FOC and FOB (two exercises performed forwards), very similar angular values are observed. The BIB is executed backwards and shows some differences compared to the other two. In this exercise, the athletes show more marked initial flexion and maximum trunk flexion. On the contrary, the final flexion angle is the less marked one. In the FOC, the athletes begin their movement with a more erect trunk, perform the wider flexion in the central phase from 89° to 82°, and at the end of the rotation they show a more flexed trunk compared to the other exercises.

Shoulder and pelvis angles

The shoulder torsion angles were assessed considering the bi-acromial axis and the axis between the anterior iliac crests, and the bi-acromial axis with respect to the x-axis referred to the laboratory.

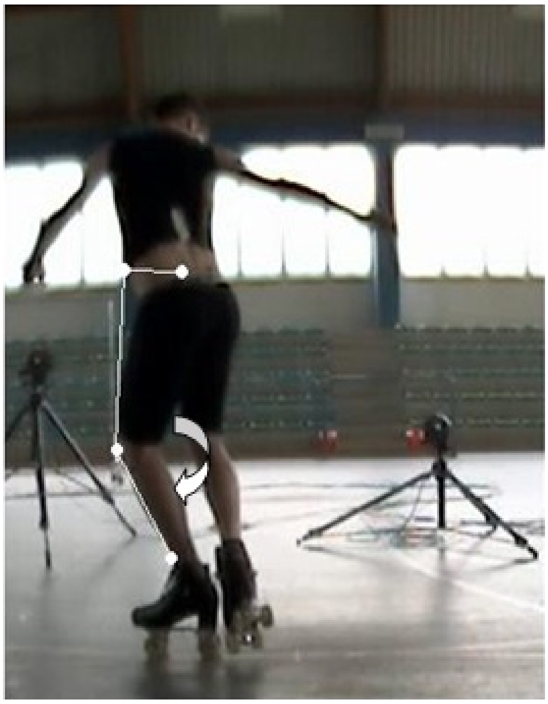


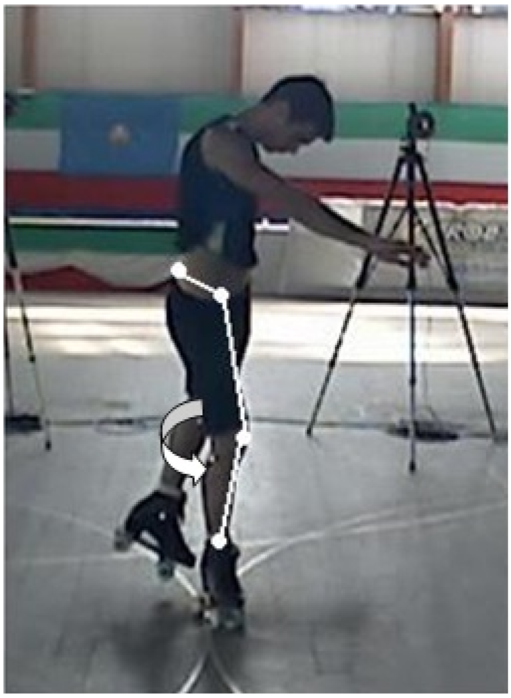
Concerning the shoulders position, we report the minimum angular values of the shoulders axis with respect to the x-axis, on which the main movement of the skaters takes place during the four exercises. Furthermore, two angles between the shoulder axis and the pelvis axis are analysed. The minimum phase displacement value between the axes, and the maximum phase displacement value during the skate rotation were considered. The athletes show a very similar behaviour in the three exercises.

In the FOB, the shoulder are more aligned on the x-axis, whereas with respect to the pelvis they show a more marked phase displacement compared to the other exercises, for both the minimum and the maximum values. Therefore, in this case the athletes show a higher torsion compared to the other two exercises. The BIB show the biggest phase displacement with respect to the trajectory, but the shoulders are more aligned with the pelvis. The minimum and maximum phase displacement in the BIB and the FOC are similar.

Supporting leg data

The knee angle was assessed considering the hip (anterior iliac spine), knee and ankle markers of the supporting leg.





In the goniogram of the knee during the support, the values relative to three movements of the rotation phase are highlighted: the initial loading angle, the maximum extension recorded in the skate rotation phase, and the knee loading angle at the end of the rotation.

Individual behaviours on the knee during the loading phase are very different. Therefore, it can be interesting a single case analysis such to individuate groups of subjects showing the same movement characteristics. Before carrying out this analysis, it is interesting to consider the average statistical indices. From these parameters, it turns out that in the BOC there is a trend to flex more the knee during the initial loading, and to reach the highest extension value. Furthermore, at the end of the movement the loading is reduced. This exercise shows the highest difference between initial loading and maximum knee extension, and, at the same time, the minimum difference between that knee extension and the loading at the end of the rotation. The initial loading in the FOB and FOC is less evident, i.e. in the exercise preparatory phase the athletes keep the knee more extended. The maximum loading at the end of the movement occurs in the FOC, where the knee is more flexed compared to the initial loading.

It is possible to analyse the behaviour of the supporting leg in the single athletes through spaghetti graphs.

In the BOC graph, angular values may be observed that are different only in the initial loading phase. Some of the subjects start with a more pronounced flexion (e.g. F.G.), whereas others (V.G) show a less evident loading in the initial phase.

During the maximum extension, the values oscillate between 172° and 180° and it is difficult to individuate subgroups of subjects. Also in the final phase of the movement the behaviour is more homogeneous compared to the other exercises, with values oscillating from 170° to 177°. Therefore, the loading in the end-movement is barely hinted.

In the spaghetti graph of the FOC, three groups of subjects can be identified. The first group (P.A.,S.M.) shows the more pronounced loading in all the three phases. The second group shows the highest angular values in the three phases, with a nearly extended knee in the central point, and a very heterogeneous behaviour at the end of the rotation. In this exercise, there is an intermediate group as regard to the knee angular values.

Concerning the knee angles in the BIB, two groups of subjects are easily identifiable. The first group (C.C., F.G., P.A.) clearly shows the lowest angular values in all the three considered points. In this group, the angular values show a rather pronounced loading in the preparatory phase (152°-163°), an about 167° value at the maximum extension, and a little 2°-5° loading at the end of the movement. The second group of subjects (L.S., N.F.,V.G., C.E.) show a clearly more marked knee extension in all the three phases. In the initial phase, the angles is between 174° and 178°; the maximum extension corresponds to about 178°, and the loading at the end of the movement does not show a unique behaviour. Two subjects show a marked loading (168°), whereas others tend to maintain the maximum extension values. A third subgroup shows intermediate values. A subject shows a peculiar behaviour: he starts with a pronounced loading, extends completely the knee in the central phase, and loads slightly at the end of the movement.
The spaghetti graph of FOB shows two clearly distinct groups of athletes. The group with a pronounced loading (F.G.,P.A.,S.M.) shows an angle oscillating between 161° and 166°, a few pronounced maximum (between 168° and 172°), and a not very marked loading at the end of the movement. The other group starts with a more extended knee (170°-175°). Then, they extend almost totally the knee. At the end of the rotation, they show a very heterogeneous behaviour: some of the subjects loads markedly, whereas other display slight loadings. For example, an athlete ends the exercise with a knee angle of 160°, whereas another shows a 173° angle at the end of the rotation.

Conclusions

Temporal data

The longer duration of pivot phases of the wheels in the BIB can be related to the wider spaces in the direction of the movement observed in this exercise. The counters, being more precise on the linear spaces, show a shorter duration of the pivot phases.

Spatial data

The brackets are the exercises with the highest error trend in the direction of the movement. It seems that the athletes, to maintain the trace, delay the movement on the x-axis. In the BIB the athletes perform the exercise most delayed. A possible explanation is that they have a worst visual feed-back compared to the other exercises, due to the body and the swinging limb position, blocking a good vision of the trace. This leads to conclude that the BIB is the most difficult exercise. The counters are more precise on the x-axis, but they show a wide trend to make mistakes on the z-axis. In this case, the subjects search for the following trace, as they must perform a change of circle.

Kinematic analysis of the limbs

Concerning the support leg, we can state that the initial, more marked in the BOC, loading and maximum extension can be explained as an attempt of the athlete to lighten the skate during the rotation. This can be related to the shorter times of the pivot phases of the wheels. Furthermore, this explains a more fluid action of the skate in the counters. The loading at the end of the rotation is more marked in the FOB. This is probably due to a wider seeking of the trajectory and the dynamic equilibrium, as the exercise ends backwards. The presence of groups of athletes executing similar movements, as displayed by the spaghetti graphs, are probably due to a given exercise interpretation set by the provenance school. Different strategies in the sequence of movements are observed also about the free leg adduction. Probably, this is justified by the pelvis rotation, being counterclockwise in forwards exercises, and clockwise in backwards exercises.

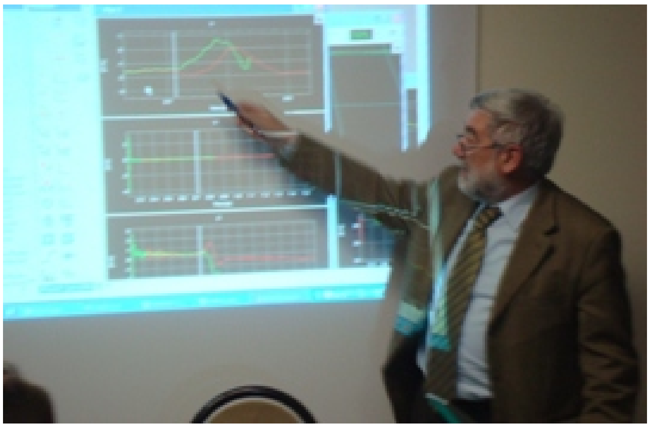
Trunk data

The different behaviour in BIB about the trunk flexion can be explained considering that the BIB is the only, amongst the three examined exercises, that is performed backwards. The initial flexion is more marked due to a bigger difficulty to see the trace.

At the end of the rotation the athlete, finding himself in a forward position, extends more the trunk compared to the other exercises. The shoulder rotation with respect to the x-axis and the pelvis is probably due to the position of the athlete that is required in the exercise.

The text is an excerpt from a Sports Sciences dissertation by Micaela Orlandi, entitled “Biomechanics of obligatory exercises in artistic roller skating”, Supervisor Prof. Franco Merni, Faculty of Exercise and Sport Sciences, University of Bologna. Academic year 2008/2009.

Prof. FRANCO MERNI



After graduating "cum laude" in Medicine and Surgery at the University of Bologna, thesis "Experimental applications of Biomechanics in functional anatomy" , he achieves in the following year the license to the practice of doctor, and since then he belongs to the Federation of Sports Medicine . From October 1, 2002 he is called as professor, by the Faculty of Sport Sciences in Bologna and since then he has taught 'Theory and Methodology of Training' and 'Motor and Aptitude Evaluation in Sport' in Bologna and since 2004 in Rimini.

From 1972 to 1988 he conducted research in the field of motor development with institutions and structures.

As director of the Laboratory of Biomechanics of ISEFof Bologna by the Institute of Anatomy ,he has developed equipment and software procedures for the analysis with film methods of: speed, jumping, throwing in athletics, speed skating, jumps of gymnastics and artistic skating, cross -country skiing alpine skiing techniques, volleyball and ballet. For this research in 1983 he won a scholarship from the Italian Olympic Committee.

He attended as speaker 30 experimental theses of the ISEF and Sports Medicine of the University of Bologna, which were honored by CONI as the best sport thesis at national level.

Since 1980 he has worked as a consultant and researcher with the Italian Olympic Committee and various sports federations, including: the School of Sport of CONI, Basketball, Cycling Federation, Athletics.