Traditional high jump Gusimbuka Urukiramende: could early 20th century African athletes beat Olympic champions?

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Abstract

During the first half of the 20th century extraordinary high jumping performances of East-African athletes were observed. These athletes used a specific native jumping style called Gusimbuka Urukiramende. Eye-witnesses believed that these performances could have been world-records and that these athletes could have competed at the Olympics. However, these athletes never participated in international competitions and there is no other proof to support these performance claims. We have analysed historical photos and cine sequences of these jumps, documented the movement analysis of this technique, quantified performance and compared it to contemporaneous elite performances. Our analyses demonstrate that Gusimbuka Urukiramende athletes did not jump as high as the world record. Nevertheless, even though they used a suboptimal jump technique (because they had to lift their bodies higher to cross the bar) they could cross bar heights of 188 cm or 135% body height and as such still was worthy of participation to the Olympics.

Video abstract

To be made

Keywords

High jumping, performance analysis, movement analysis, historical data, Gusimbuka Urukiramende, African culture

Introduction

During the first half of the 20th century impressive high jumping performances by East-African athletes were reported by European spectators in Rwanda. Photos and cine films taken by these eyewitnesses show African men jumping above people standing underneath the high jump bar. In their reports and film voice-overs they speak of heights of up to 2.50 m [1–4]. In enthusiastic comments they describe these performances as fit for the Olympics [5], or even a spectacle that has never been seen at the Olympic Games [1]. Some describe these athletes as "the real world champions" [4]. A picture in the archives of the MRAC Tervuren (by CMS) claims to depict a world record at that time. Even more, the aforementioned height of 2.50 m would still beat today's world record of 2.45 m set by Javier Sotomayor in 1993 [6]. Yet, these African athletes never competed internationally, as such the above claims could not be validated.

Some literature has been published on the topic of "Gusimbuka Urukiramende", which is the native name for this East-African high-jumping style: John Bale described the sociology of the phenomenon [7,8] and Jokl published a qualitative movement analysis [9]. However, none offer an objective appreciation of the jump heights achieved as high jumping in East-Africa was not an organized sport just like it was in the Western world.

In and around the first half of the 20th century, Gusimbuka Urukiramende was part of ceremonies during which local historical and military traditions were showcased. The young men that participated in these ceremonies seemed to be exceptionally gifted and trained in jumping using the Gusimbuka Urukiramende technique. These athletes had been selected during local competitions to receive long intense training and education in specialized programs. These programs were called the itorero and took, amongst others, place at the royal court. Training was aimed to turn young men in perfect courtiers and distinguished warriors, so they could become role-models for the people of the country. Therefore they practiced several warrior skills including the high jump, which finds its origins in traditional warfare: soldiers needed to be able to jump over hedges and fences of villages to launch an attack or to retreat in case of danger [10].

To do so they used a unique technique described by Jokl [9]. Where African athletes jumped barefoot from a stone, kept their trunks forward oriented (ready to e.g. launch a spear) and landed on their feet (ready to attack or to run) [10], Western athletes competing with the Western roll jumped shod, oriented their trunks towards the bar and landed on hands and feet and rolled onto their backs [11,12], The rather upright trunk during bar clearance suggests that in Gusimbuka Urukiramende, compared to the Western roll, the apex of the flight path of the body centre of mass is higher when clearing the same bar height. As a consequence, more push off work is needed, which makes the supposedly reached Gusimbuka Urukiramende jump heights of the African athletes even more astonishing.

Nevertheless, to our knowledge, heights of these historical African jumps were never measured using biomechanically valid methods such as video analysis to validate the above claims. Nor could we find any evidence of East-African athletes competing internationally (in which bar height would have been measured accurately). So, the question remains: how high did East-African Gusimbuka Urukiramende athletes really jump? If the claims of exceptional heights could be confirmed, there would be reason to believe that some athletes possessed the talent

to jump very high. This might be related to a genetic potential that could still be present today [13]. If further developed within a modern performance support framework, there might be the potential for elite high jumping performance nowadays.

Using historical cine films and photos - that have never been analysed before - we set out to objectively quantify jump heights achieved by Gusimbuka Urukiramende athletes using biomechanical research methods. Aditionally, we wanted to qualitatively describe the movement execution of Gusimbuka Urukiramende based upon the available films and photos. Finally, we aimed to compare how performances of Gusimbuka Urukiramende compare to the ones observed in contemporaneous competitive high jumping.

Methods

Archives of the KADOC-KU Leuven, Cinematek, VRT and the Royal Museum for Central Africa Tervuren were searched for recordings of high jumping by African athletes. Of the 5 cine films and 68 photos retrieved, 2 cine films [4,14] and 3 photos (Van Overschelde, 1939, third photo unknown photographer, 1934) (see electronic addendum) were used for biomechanical analyses, giving a total of 22 jumps of at least 11 athletes. Photos and cine sequences were selected for inclusion using the following criteria: (1) image quality had to be sufficient to allow biomechanical analyses (i.e. the images had to have a sufficient resolution and not suffer overly from movement artefacts) and (2) based upon qualitatively comparing jump height to the stature of the athlete or spectators jump heights seemed maximal or close to maximal. Furthermore, the inclusion of cine films strengthened our analyses as they are almost impossible to tamper with in contrast to photos which were debated to potentially have been falsified [7].

The original cine films were digitized to high-quality images using the Filmfabriek HDS+ scanner with Wetgate scanning technology and VirtualDub software v1.10.1. Vibrations/shaking of the images were removed by transforming (translating and rotating) the images to have a zero frame by frame offset for fixed points (bar stands). Images were then rotated to match a gravitational frame of reference by using the cephalo-caudalo axis of people standing in an upright position as a reference for the orientation of gravity. Markers were placed on meaningful points in the 2D-images using MaxTraq-software from take-off until landing. The athlete was represented using a 16-segment kinematic model (marker placement as described by Winter [16] and mass distribution by Dempster [17] which allowed to calculate the position of the BCOM (body centre of mass). Position of the lowest point of the body in the vertical plane of the bar, the ground and bar were also tracked in the images. Perspective in the cine films was accounted for by applying scaling factors based on perspective-induced changes in segment lengths. For this segments were selected that for a period of time did not rotate out of the plane of focus. A constant movement speed relative to the camera was assumed, as such we adopted a linear change in distance from the camera relative to time. Therefore, the observed change in segment length could be modeled by the following function: observed change in segment length = (scaling factor / frame number) + scaling constant.

The photos were digitized using the same software and model used for the cine films. Body height of the spectator underneath or next to the bar was also digitized. For the spectator standing next to the bar, body height was corrected for perspective, by applying a linear scaling factor that was based upon the difference in bar height (from base of the stand to resting position of the bar) between the left and right bar stand.

The following variables were calculated relative to ground level (h_{GROUND}, see Figure 1). The maximal height of the BCOM during bar clearance ($h_{BCOM\ MAX}$) was defined as the apex of the least squares parabolic fit (height of the BCOM versus time) for cine films. For photos, this height could only be calculated for those images showing the exact instance of bar clearance. Bar height (h_{BAR}) was defined as the lowest point of the upper side of the bar. $h_{BODY\ LOW}$ was defined as the lowest point of the body in the vertical plane of the bar. This height determines whether the bar is cleared or not (bar clearance only when $h_{BODY\ LOW}$ is higher than h_{BAR}).

Gusimbuka Urukiramende athletes took off from a stone, slope or termite hill of approximately 25 cm high. This increased take-off height was a performance enhancing feature, which had two main benefits. The athletes gained height at take-off as the stone raised the starting point of the BCOM's parabolic flight and additionally the vertical velocity at take-off increases, contributing to an increased jump height. The following mechanism explains this effect: by jumping upwards towards the take-off stone, the athlete's BCOM already had an upward velocity at the start of the last contact leading into take-off, whereas there is a downward velocity at that point in time for a non-elevated take-off. If the athlete then applied a same vertical force impulse during this contact, vertical take-off velocity was larger for the former, which elicited an added beneficial effect on jumping performance [18,19].

Take-off height on the stone ($h_{TAKE\text{-}OFF}$) was defined as the position of the toes of the take-off foot at take-off in the cine films. For the photos the maximal possible height at which the foot could have been placed was taken, i.e. stone height. h_{GAIN} is defined as the benefit of taking off from the stone (instead of ground level) due to its beneficial effect on take-off velocity.

In order to calculate the net jumping height (h_{NET}), h_{GAIN} should be determined for the Gusimbuka Urukiramende jumps. h_{GAIN} for each Gusimbuka Urukiramende jump could be estimated based on research in which modern time high jumpers were trained to jump from a 0.19 m elevated surface (using the Fosbury technique) [18,19]. Not including the outliers in the 1993-study, the athletes gained an average of 5 cm (3% BH). The Gusimbuka Urukiramende athletes used a similar take-off height [10], as such we estimate their h_{GAIN} to be 3% as it is for the Fosbury athletes.

By including h_{GAIN} into the calculations, the net jumping height could be calculated: i.e. the maximal bar height that the athletes possibly could clear when taking off from level ground correcting for the twofold beneficial effect of the raised take-off ($h_{NET} = h_{BODY\ LOW} - h_{TAKE\text{-}OFF} - h_{GAIN}$).

For the selected photos we could scale these heights to an absolute dimension (known body height, BH, of people on the photos), thereby expressing performance in meter. For the film images no spatial calibration (to meter) was possible since absolute distances are unknown. Furthermore, given that framerate of the cine films was unknown, a spatial calibration based on the ballistic path of the BCOM as determined by gravity also was impossible. Therefore, performance is reported relative to body height of the athlete, which was defined as the distance between heel and crown at the instant of take-off, during which we see the most extended body position of the athlete.

We also aimed to compare performances of Gusimbuka Urukiramende athletes to contemporaneous elite athletes. The variables to be compared between both populations should be carefully selected. The heights reported in international competitions are bar heights. Yet, bar height does not represent the performance of the African athletes, since (at least in the sequences analysed) they jumped much higher than the bar: h_{NET} mostly still is a lot higher than h_{BAR}. Therefore, we will rather use h_{NET} of the Gusimbuka Urukiramende athletes. For maximal performances at contemporaneous international competitions h_{NET} can be considered equal to the reported h_{BAR} (since at maximal performance athletes mostly pass just above the bar). Therefore, we will compare h_{NET} of

Gusimbuka Urukiramende athletes to h_{BAR} of contestants in official competitions in the same timespan as the Gusimbuka Urukiramende recordings.

Results

A typical example of the execution of Gusimbuka Urukiramende can be found in the supplemented video. In general, this technique was characterized by a straight run up perpendicular to the bar. The last step was on an elevated surface from which the athlete took off with a forceful flexion-extension of the take-off leg combined with an upward movement of the contralateral (from now on referred to as swing leg) and a double arm swing. If any rotation was present it concerned a rotation along the longitudinal axis of the body, in which the ventral side of the trunk remained facing the bar. During the upward flight phase the frontal part of the kept facing the bar. The swing leg crossed the bar first with flexion at the level of the hip and an extended knee. At the same time the foot of the take-off leg was brought upwards by a flexion, abduction and external rotation of the hip and a flexion in the knee. The trunk could be lateroflexed, which resulted, combined with the possible twist rotation, in a sideward body position during bar crossing. During the downward flight phase the hip of the swing leg extended. The hip and knee of the take-off leg extended. Simultaneously, the hip adducted and showed internal rotation. If rotation along the longitudinal axis was present, this twist persisted in this phase. Athletes landed in a more or less extended body configuration on one or both feet, after which impact reduction was realized by forward trunk rotation and flexion in hips, knees and ankles.

The height of the BCOM of the athletes in the pictures varied between 2.31 and 2.38 m. Assuming that the pictures were taken when they reached their maximal flight height, the highest bar height the athletes in the pictures could have cleared when taking off from the raised surface varied between 2.12 and 2.16 m. Correcting for the raised take-off (0.23 m) and the additional gain (0.05 m) resulted in a maximal bar height that the athletes could have cleared without using a raised take-off (h_{NET}) between 1.84 and 1.88 m. (Table 1)

The maximal flight height of the BCOM of the athletes in the cine films was 122 +- 6% BH. The highest bar height the athletes in the cine films could have cleared when taking off from the raised surface was at average 108 +- 5% BH. Correcting for the raised take-off (12 +- 2% BH) and the additional gain (3% BH) this causes, left a maximal bar height that the athletes could have cleared without using a raised take-off of 93 +- 6% BH. (Table 2)

Discussion

Our movement description resembles the one that has been published previously [9].

The calculated body centre of mass heights in the pictures were on average 2.34 m. This height is in close proximity to the estimations based upon visual impressions mentioned in the historical reports (see introduction). However, the maximal bar height that could have been crossed at average is markedly lower (2.14 m). This height is similar to the performances up to 2.18 m reported by Jokl [9]). As mentioned before, the athletes used a raised take-off surface of about 0.23 m. This height and the additional gain it provokes (0.05 m) also had to be subtracted to obtain the average net jumping height of 1.86 m, which is markedly lower than the reported heights and record-claims.

The cine film sequences provide additional information. Yet the calculated heights in the cine films were expressed in body height of the athletes due to a lack of spatial calibration. The Watutsi in general are tall and slim people. Their average body height is 1.75 m, but it is likely that athletes excelling in jumping were taller than that [9]. Assuming they could be almost as tall as their kings (Mutara, 2.03 m; Charles III Rudahagwa, 2.06 m [20]) and measured around 2.00 m, we could recalculate the performance expressed in body height to absolute dimensions. Using this estimate, maximum heights of the BCOM in the cine films would have been at average 2.44 m (= $h_{BCOM\ MAX}$). Again, maximal flight heights of the BCOM are close to the ones reported by the eye-witnesses. After correcting for the raised take-off they could have cleared bar heights of at average 1.86 m (= h_{NET}). These absolute results however remain speculative because of the rescaling to an estimated athlete body height.

Without a doubt, some of these athletes performed very high jumps. In order to appreciate the performance level of the Gusimbuka Urukiramende jumpers and justify the world-record and Olympic-performance claims, we can compare their maximal jumping heights to those of elite jumpers worldwide at that time. We can do this quite straightforwardly for the photos. For the cine sequences we recalculate jump height based on the assumption of an athlete body height of 2.00 m.

Did Gusimbuka Urukiramende jumpers achieve world record heights? Our evidence does not support this claim. At the time the pictures where taken (1934-1939) the official world record increased from 2.06 to 2.09 m. In the best jump in the pictures only a bar height up to 1.88 m could have been cleared without using a raised surface to take off from, which is markedly lower than the world record height. 1.88 m would only have been a world record performance prior 1876. In defence of the Gusimbuka Urukiramende athletes, the pictures might not have been taken at the highest point in their flight. So, their jump heights could have been a little bit higher, but the difference probably still wouldn't bridge the gap to the contemporaneous world record. Unfortunately, we cannot weigh up results from our cine sequences to the world record evolution, as we could not retrieve body heights of all contemporaneous world record holders.

Additionally, world record performances are unprecedented performances of exceptional athletes. It would have been a very lucky coincidence that such a phenomenal event was captured in our limited database of quantifiable Gusimbuka Urukiramende jumps. Therefore, we broaden our scope by investigating the claim that Gusimbuka Urukiramende jumpers could have delivered performances worthy of participation to the Olympic Games, let alone excel at the Olympics? For this question, the answer is yes.

As a reference we use the official jumping heights of the Olympic high jumping event finals in the same timespan as the Gusimbuka Urukiramende recordings (pictures: 1934-1939, cine films: 1934-1952). For the photos, absolute performances (in meter) can be compared. Since for the cine films only relative performances (expressed relative to body height) can be compared, performances of Olympic athletes were also scaled to body height, as these are available through various online platforms (sports-reference.com, Wikipedia).

The average of the collection of historical jumps (1.86 m for the pictures and 0.93 BH for the cine films) is within the range of performances by Olympic finalists (figure 2), which is already a remarkable fact indicating that

Gusimbuka Urukiramende athletes would have been able to participate to the competition. In reality, countries send a selection of their best athletes to the Olympics. So, we can also narrow our results down to only include a selection of the best Gusimbuka Urukiramende athletes. The three photos included in this article were already selected to qualitatively show the highest jumps in the entire collection (68 photos). Therefore, these three will be used for the comparison. We also select the four best athletes based upon the cine films. The comparison of these 7 best Gusimbuka Urukiramende athletes and Olympic finalists indicates that during 1936-1952, top Gusimbuka Urukiramende athletes were capable of performing at the level of Olympic finals. Moreover, if Olympic performances would be measured in terms of the height reached relative to the athlete's own body height, the very best of the Gusimbuka Urukiramende athletes, jumping up to 106% of their body height, would have been able to compete for medals at the Olympics.

The present research has got three main limitations: 1/ jump height might have been underestimated, 2/ jump height might have been overestimated and 3/ suboptimal accuracy of the data. All of these are discussed in the following paragraphs.

It is not certain whether the jumps that were captured on photographs and cine films reflect the maximal jumping capacity of the East-African athletes. First it is not certain that our limited study sample contains the best performances. The jumps in our collection were performed during ceremonies rather than during competitions. As such the intent might not have been to achieve a maximal jumping height, but rather to deliver an aesthetically pleasing demonstration. Second, as mentioned before, the analysed pictures might not show the highest point in flight. Third, the circumstances and equipment of the Gusimbuka Urukiramende athletes was suboptimal compared to the contemporaneous Western contestants. It could be debated whether Gusimbuka Urukiramende athletes could have jumper higher if their run-up would have been executed on a level athletics surface instead of a natural field and if they would have been wearing proper athletics shoes instead of jumping barefoot. And finally also their technical execution of the bar crossing itself might be a limiting factor. The rather upright trunk position during bar crossing in Gusimbuka Urukiramende is a typical feature that found its origins in warfare traditions (see introduction). This implies that the body centre of mass had to be lifted about 14% BH higher than the lowest part of the body in the vertical plain of the bar to cross the bar without making it fall. In the contemporaneous Western Roll technique the body passed more gradually over the bar, allowing for a more efficient bar crossing (ie. lower BCOM relative to the lowest body position). Nowadays the Fosbury flop is considered the most optimal high jumping technique. Based on our calculation of existing data-sets [21,22], the BCOM only passes 1 to 2% BH over the lowest body point in the Fosbury flop. If Gusimbuka Urukiramende athletes would master this more efficient jumping technique they might as such be able to jump even 12% BH higher than they did when using the Gusimbuka Urukiramende technique (figure 3).

The use of the stone to take off from and its potential effects on performance can also be further debated. In this study we have used data collected on modern high jumpers to determine the additional gain in jumping height.

However, it could be argued that Gusimbuka Urukiramende athletes might have been better trained to use and exploit this stone compared to the modern high jumpers. As such, h_{GAIN} could still be underestimated in this study. On the other hand there is probably also a limitation on the ability of the take-off leg to produce an equally powerful push-off when the BCOM already has an upward flight velocity.

This study solely used existing historical sources. These were aimed to provide aesthetically pleasing images of Gusimbuka Urukiramende and not allow specifically for detailed biomechanical analyses. Although we selected the cine films and photos on the basis of their suitability for movement analysis; the set-up was suboptimal compared to modern-day accepted movement analysis methods. Therefore, the accuracy of the calculated values is not as high as what could be achieved nowadays in a research setting. Lack of information on body height of the Gusimbuka Urukiramende athletes meant that we had to express their jump height relative to their body height and not in absolute values that could be easily compared to contemporaneous performances.

Conclusions

The current article provides a movement description of Gusimbuka Urukiramende as performed during the first half of the twentieth century in Africa. The analyses demonstrate that these athletes could raise their body centre of mass up to 2.34 m, which is close to the claims made by eye-witnesses of the exceptional jump heights they observed. There is however no evidence to support that Gusimbuka Urukiramende athletes could deliver world records in high jumping. Yet, during 1936 - 1952, some African athletes using the Gusimbuka Urukiramende technique could have competed in Olympic finals.

Declaration of interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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Appendices

See digital content (video)

Tables

Table 1: Gusimbuka Urukiramende performance expressed in absolute values as calculated from three different photos. $h_{BCOM\ MAX}$ = the athlete's body centre of mass height; $h_{BODY\ LOW}$ = the height of the lowest point of the athlete's body in the vertical plane defined by the bar; h_{BAR} = bar height; $h_{TAKE\text{-}OFF}$ = height of the stone the athlete used to take off from; h_{NET} = the highest bar height the athlete could have crossed without using the raised take-off from the stone ($h_{NET} = h_{BODY\ LOW} - h_{TAKE\text{-}OFF} - h_{GAIN}$). h_{GAIN} = the additional height gained due to a higher take-off velocity by jumping from an elevated surface; for all three pictures equal to 0.05 m.

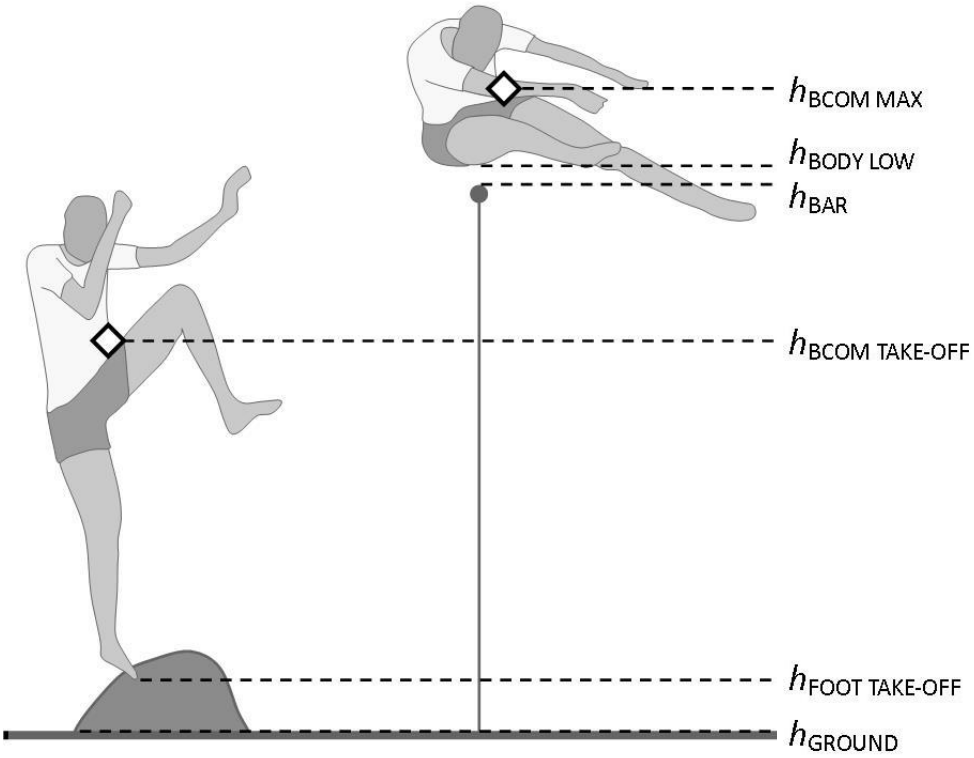
[*1] position of the crown of the head (which is in this picture obscured by the hat) was calculated based upon facial characteristics measured in other pictures. [*2] [23][*3] $h_{TAKE\text{-}OFF}$ for J1 and J3 were taken from J2.

Jump	J1	J2	J3
			
Year	1934	1939	1939
Person	Queen Astrid	King Mutara	King Mutara
Body Height (m)	1.815 [*1]	2.032 [*2]	2.032 [*2]
$h_{BCOM\ MAX}$ (m)	2.38	2.33	2.31
$h_{BODY\ LOW}$ (m)	2.16	2.13	2.12
h_{BAR} (m)	n/a	2.07	2.04
$h_{TAKE\text{-}OFF}$ (m)	0.23 [*3]	0.23	0.23 [*3]
h_{NET} (m)	1.88	1.85	1.84

Table 2: Gusimbuka Urukiramende performance expressed in body height as calculated from movie sequences. 19 jumps by 8 different athletes. $h_{BCOM\ MAX}$ = the athlete's body centre of mass height; $h_{BODY\ LOW}$ = the height of the lowest point of the athlete's body in the vertical plane defined by the bar; h_{BAR} = bar height; $h_{TAKE\text{-}OFF}$ = height of the stone the athlete used to take off from; h_{NET} = the highest bar height the athlete could have crossed without using the raised take-off from the stone ($h_{NET} = h_{BODY\ LOW} - h_{TAKE\text{-}OFF} - h_{GAIN}$). h_{GAIN} = the additional height gained due to a higher take-off velocity by jumping from an elevated surface; for all three pictures equal to 3% body height.

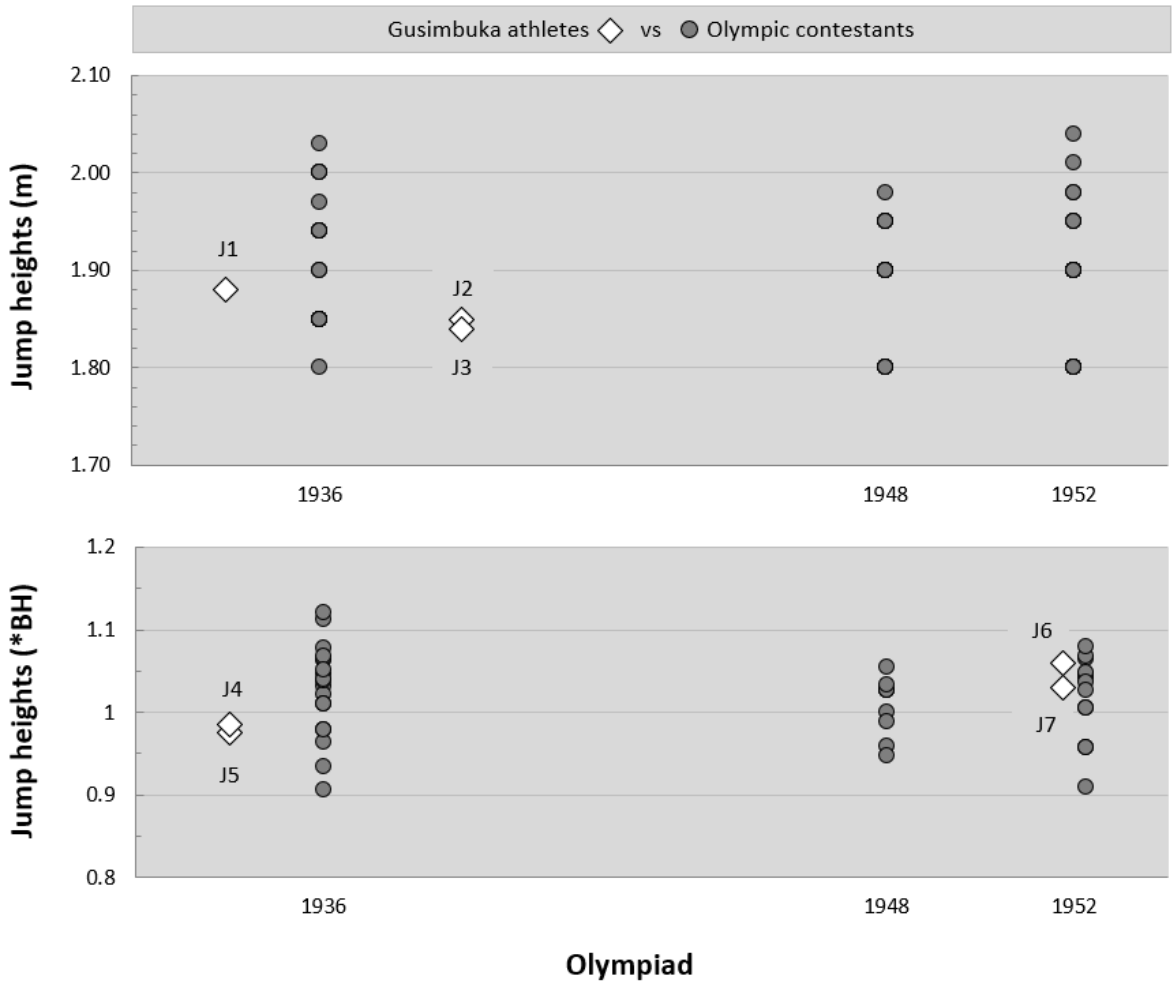
		CINE FILMS (19 jumps by 8 athletes) (*body height)				
		Mean	**±**	**Standard deviation**	**Minimum**	**Maximum**
$h_{BCOM\ MAX}$		1.22	±	0.06	1.13	1.35
$h_{BODY\ LOW}$		1.08	±	0.05	1.02	1.22
h_{BAR}		1.04	±	0.06	0.96	1.20
$h_{TAKE\text{-}OFF}$		0.12	±	0.02	0.08	0.16
h_{NET}		0.93	±	0.06	0.85	1.06

357 Figures



358

359 Figure 1: visual representation of variables constituting jump height.



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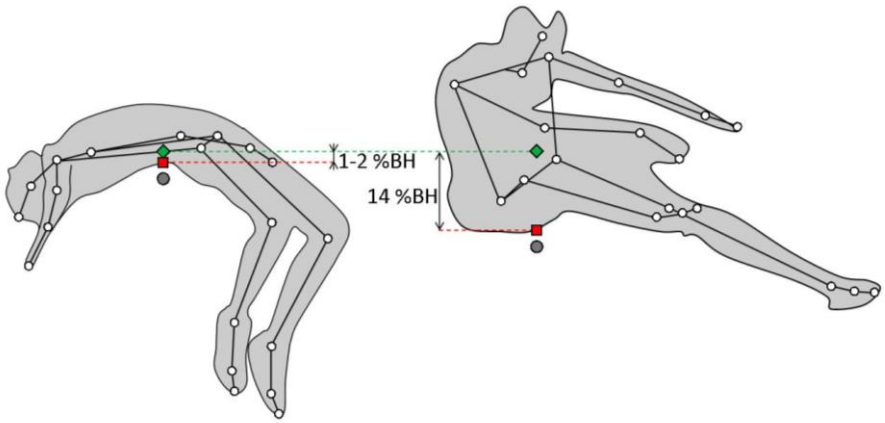
361 Figure 2: Comparison of Gusimbuka Urukiramende performance (horizontal lines and band) to Olympic
362 performances. In the top panel the three best Gusimbuka Urukiramende jumps from photos (J1-J3, white
363 diamonds) are compared to absolute performances of all Olympic contestants. In the lower panel the four best
364 Gusimbuka Urukiramende jumps from cine films (J4-J7, white diamonds) are compared to performances relative
365 to body height of all Olympic contestants.



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367 Figure 3: Comparison of bar crossing efficiency in the Fosbury flop (left) and Gusimbuka Urukiramende techniques
368 (right). The diamond ◊ represents the highest point of the trajectory of the BCOM. The square □ represents the
369 lowest point of the body when crossing the bar. The circle o represents the bar.

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Figure captions

Figure 1: visual representation of variables constituting jump height.

Figure 2: Comparison of Gusimbuka Urukiramende performance (horizontal lines and band) to Olympic performances. In the top panel the three best Gusimbuka Urukiramende jumps from photos (J1-J3, white diamonds) are compared to absolute performances of all Olympic contestants. In the lower panel the four best Gusimbuka Urukiramende jumps from cine films (J4-J7, white diamonds) are compared to performances relative to body height of all Olympic contestants.

Figure 3: Comparison of bar crossing efficiency in the Fosbury flop (left) and Gusimbuka Urukiramende techniques (right). The diamond ◊ represents the highest point of the trajectory of the BCOM. The square □ represents the lowest point of the body when crossing the bar. The circle o represents the bar.