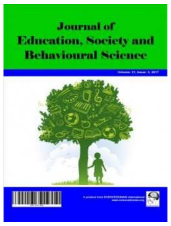

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Inertial Force in Sport and Fitness with Hula Hoop as an Example

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Survival issues are not only related to the competition against other ecological intruders for the same natural resources, but also to cope with many natural laws and physical principles which are modeling our behaviors and choices. Inertial force is very present in nature and evolution and knowing its modes or appearance would help us to use it for our benefit in our sport evolution. In sport practices inertial force is one of the resistance that people have to fight against for making aerobic exercises. General fitness are based partly in resistances to the inertial and other forces while mass muscle and strengths overcome them in opposition to these strong laws of nature. For instance, while playing hula hoop the inertial force can be used to build beautiful trick or performances as briefly described in this text. This rule of nature is present both to keep the symmetrical circle shape of the hula hoop and to preserve the movements/stillness in constant velocity or orientation. This text is aiming to collect information to described the inertial force in different expressions in nature, to understand its presence in order to include the knowledge in sport trainings plan for better results.

Keywords: Inertial force; hula hoop; fitness; fly; temperature; phylogenetic inertia.

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1. INTRODUCTION

Inertial force is present in all the mass and physical objects, consisting in a resistance to any change in the state, including motion, speed, direction or rest, pursuing in keeping constant their parameters such as velocity, shape, *momentum* (or impulse as the product of mass and velocity of an object), straight line, etc. The words come from Latin (*iners*) meaning idle, sluggish. It was firstly described by Isaac Newton as a quantitative and measurable property of physical systems: "The *vis insita*, or innate force of matter, is a power of resisting by which everybody, as much as in it lies, endeavors to preserve its present state, whether it be of rest or of moving uniformly forward in a straight line".

Hula hooping is a complex skill in which an unstable object, a hoop or a perfect ring in its circle shape and spherical symmetry, is kept in steady oscillation parallel with the ground or other planes by means of coordinate oscillations of different parts of the body (waist, hips, arms, legs, neck, knees, ankles, etc.), in uncountable variations of creativity or imaginative flows [1]. The activity of dancing a hula hoop is based on several physical laws, such as inertia, gravity, rotation, torque forces, centripetal forces, friction, or eccentric movements. In this text we are treating the inertial force as an important physical law that is present in the hula hoop symmetric shape and its movements as well as being part of some reasons in the fitness resistance for cardio and balance exercises. For that goal, we are describing bellow the inertial force in different expressions of nature and animal kingdom, to illustrate the importance of inertial force for adaptation and survival. The main content of the text is the inertial force in sports with hula hoop as an example.

2. BALANCE AND FORCE

To explain this concept, we would like to mention the medical sentence by Ormiston in 2013 about vein stents: "*The basic design of all stents, hoops that provide radial strength and connectors that hold the hoops together, is a balance of desirable characteristics*" [2]. Clearly, a balance of desirable characteristics is a very common goal in Medicine and Psychology, as well as in other healthy disciplines, such as in sports. Balance is achieved when constant and several points of force are working together at the same time with similar intensity to keep something in a equilibrium, which might be altered if any point of that balance is broken. The same as happens, for instance with a bicycle or any vehicle wheel [3]: if any radius or spoke is released from the whole structure, a decompensation in the entire tension happens and the normal rotation while using might be causing damage to the tyre or even the inner tube. Then a balance might be considered as a equilibrium of forces. But balance is also present in object that can move, for instance, static and dynamic balance are present while creatures are walking. For both balances, a series of muscles in flexion and extension through unconscious calculations (addition and subtraction) considering the gravity and the balance are carried out. Synapses with the interneurons and motorneurons are continuously shifting and firing for the movement and postural control to happen [4].

Force is described as a push or pull that includes thrust, drag and torque and it is inherent to mechanics: "*Any attempts to banish the concept of force from mechanics and to emasculate it will never move us forward, because mechanics without forces is just the same as thermodynamics without temperature*" [5]. The inertia is a force or resistance to change any previous state into a new one, but also pursuing for keeping a balance in itself. "*If there were no inertial forces opposing the accelerated motion of material bodies relative to the ether, then any randomly emerged deviations from their rectilinear and uniform motion would destroy the stability of a free or so-called inertial motion*" [5].

Sport activities might be considered somehow as a way to restore an inertial inner balance of the body metabolism. At the beginning of exercises, inertial force is present, nevertheless, each physical exercise, for instance, running, is done through a series of body changes, in a cycle from rest point to the higher activity point to rest point again, while many events happen in the body.

3. FITNESS AND HULA HOOP

Hula hoop is a circle in its symmetric spherical shape. Some of the physical resistance forces present to play it are the gravity and the inertial force, for instance [4]. Those forces are some examples about the sense of this physical activity for health and cardiovascular activity because the activity to play it is only possible to be done after some efficient competition against these natural laws that obviously have as general sports, a benefit over the health [6].

One example about how inertial force is present in the hula hoop is expressed with the movement against the floor trying to change its circle symmetrical shape around the center and to become it an ovoid shape. The automatic response of the hula hoop is to jump into the air to recover its circle shape and this is done as a trick for many different nice performances. For instance, once the jump is done, the hula hoop might possible be caught in the air when it is falling down with a hand or feet, or giving a chest or a feet blow as a ball. Another option might be to let it bounce on the floor and catch it with the feet making some hits inside the circle as a pin ball game.

However, once the hula hoop has jumped into the air as an inertial response to its shape modification, the unique movement that has been kept is an ascending-descending one, making the inertial force to restore its circle shape and that is why it is not possible to make a roll or another figure or twirl when it is falling down. Controlling the movement in this case would only be possible to be done in the up-down axis or line. That might be occurring because the length of the radio (r and R in Fig. 1) between the two points that has been modified is shortened, creating this way a decompensation in the whole equilibrium of forces that makes the circle of the hula hoop.

At this point it is important to mention the material which is made the hula hoop is relevant to consider in terms of response to tension of the circle. For instance, solid plastic is very flexible and it might have a quick and expressive answer, however, wooden or metal might behave differently. Also hollow plastic is having a smaller response because of the air inside the tube. Matters tells space-time how to bent and space-time returns the complement by telling matter how to move [7]. Inertial force is acting in two opposite points, in an linear acceleration applied as a force that has to be restored (Fig. 1). The inertial load distribution can be calculated and derived by the mathematics formula and methods [3].

4. BENEFITS OF SPORT

The ancient Greeks were very concern about promoting sports. Hippocrates himself stating: "*If we could give every individual the right amount of nourishment and exercise, not too little and not too much, we would have found the safest way to health*'. The World Health Organization (WHO) has recently reported that perseverant physical activities have benefits on various health issues such as atherosclerotic vascular diseases, hypertension, diabetes mellitus, osteoporosis, dyslipidaemia, obesity, mental health and in reduction of mortality [8]. It is well known physical inactivity is a very risk factor leading for death caused by chronic diseases. Following the Greek principle "*Primun non nocere*" (first do not harm), a proper set of exercises accordingly to each person might have an important antiaging effect.

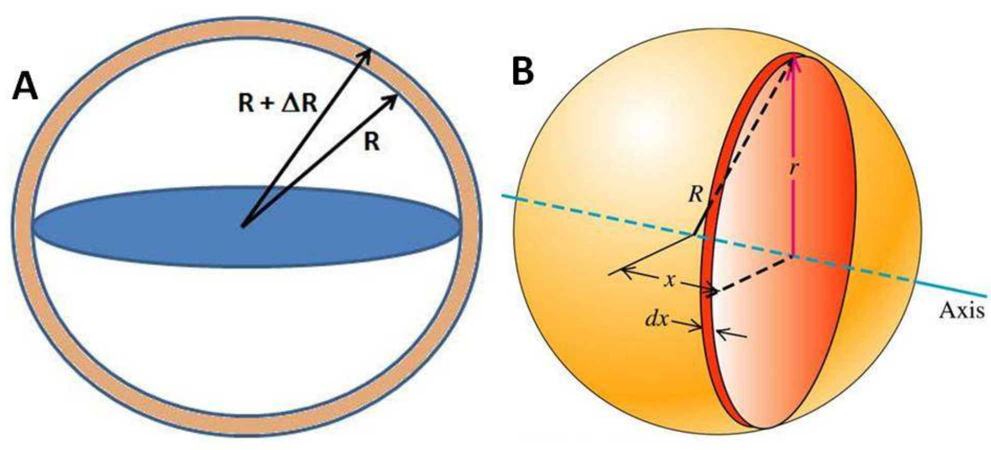

Fig. 1. Visual explanation about the inertial force in a cylinder (A) and a ball (B). The radio (R and r) is shorten in two points, then it generates a tension in the whole structure that is only relieved after the perfection is restored again recovering its previous shape. This tension creates a force that is named inertial force

5. INERTIAL FORCE IN NATURE

In nature and animal kingdom the inertial force is very present and it is even relevant for such important phenomenon as nature selection, survival or extinction. Concerning to the control of phylogenetic inertia, sexual selection may therefore be a double-edged process: promoting speciation on one hand but promoting extinction on the other. Then, the same force in nature that is inertia, might have a double use, to live or to die, such as Freud pointing out years ago with Eros and Thanatos (life and death instincts). Questions of how sexual selection linked to inertial force and related to extinction risk need closer attention from both theoreticians and empiricist [9]. For instance, in birds it was proved, having multiple sexual partners might be immunologically or energetically very costly for both males and females (increase of horizontal transfer of pathogens between individuals in a population), then no advantages for evolution [9].

For instance, birds have a huge wide range of wing morphologies and flight styles, which are reflecting the variety of aerodynamic techniques according to different inertial requirements [10]. However, pioneer classification with a precise criteria (Linnaeus, 1758) and observational work during centuries have provided many data that might proved the morphological variation in avian wing shapes have been linked with the natural phylogenetic inertia (Fig. 2). The feather mechanical properties or the body birds characteristics are not the same between birds species because different aerodynamic properties are required each case [10].

In birds, two physical principles related to the reorientation of the torso with rotational movements, have been identified while they are flying: 1) aerodynamic forces including torques and 2) inertia-based changes in angular momentum of body segments. Both considering the mass distribution and time-varying configuration as parameters [11], because inertia is measured in specific body segments depending on its resistance to the movement. Specifically in pigeons, their flights were measured and their aerodynamics and inertial-based angular accelerations of their torsos were recorded [11]. Accordingly the results, birds showed three different sorts of flights [12]: 1) the stiff-wing mode, 2) the flex mode and 3) the mixed style flex-twist mode (Fig. 3).

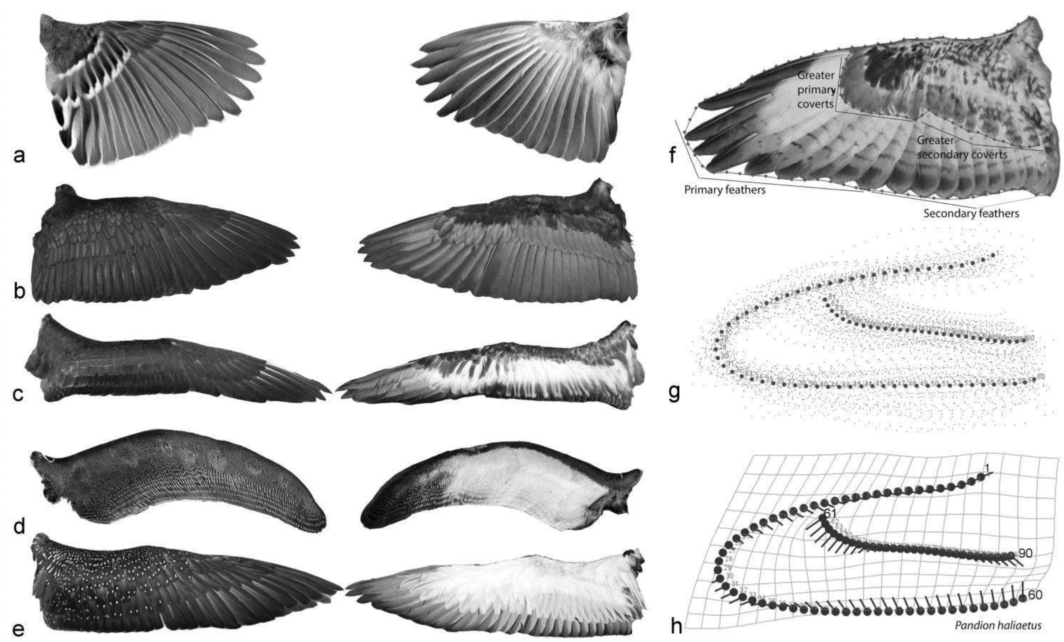

Fig. 2. From a to e, different shapes of bird wings, with distinct frictions points and resistance properties to wind or inertial force according to the animal bodies or flight styles. From f to h, schematic representation of some bird wings, having different point for primary and secondary feathers and distinct cover points which are making possible the behavior of flying

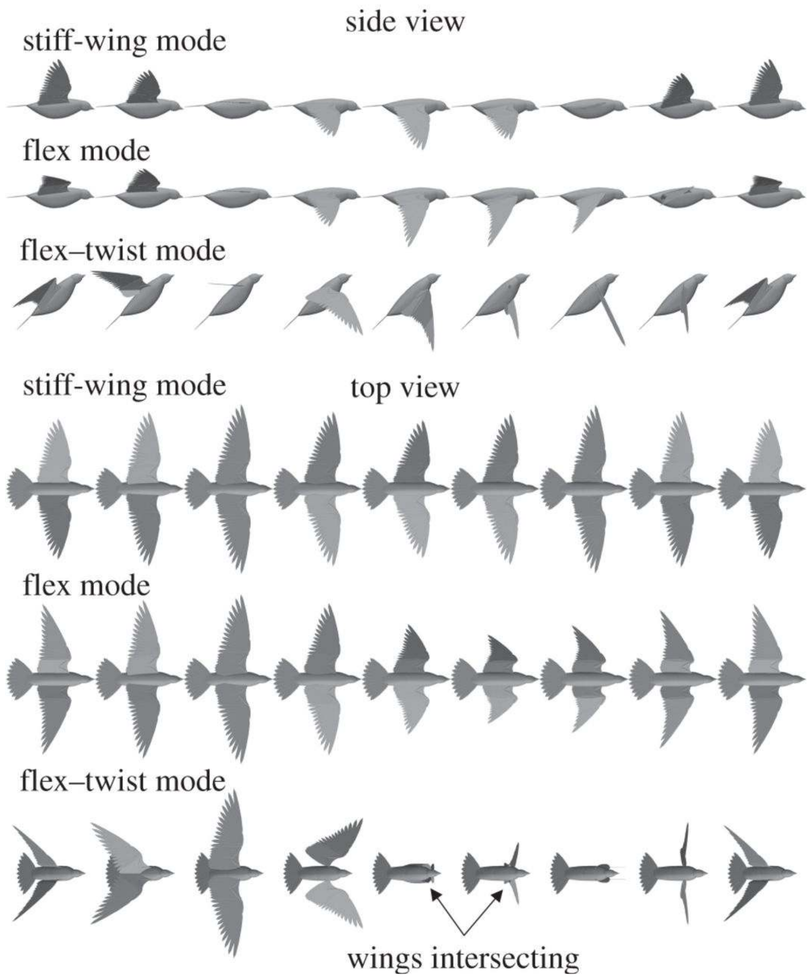

Fig. 3. Three different flight styles in two different visual (side and top views): the stiff-wing mode (1st and 4th lines), the flex mode (2nd and 4th lines) and the mixed style flex-twist mode (3rd and 6th lines). Specifically in the last style (3rd and 6th lines, flex-twist style), the wings are intersecting combining the inertia of the velocity with the braking, together with the implicit knowledge about the distance to the floor, in competition with the forces to reduce the velocity or to change the direction (from Parslew, 2015 [12], with permission)

Even the most simple movement of any bird that is taking the floor off implies many balanced calculations and resistance exercises toward the state of keeping still and quiet, against the inertia of non-movement and stay on the floor with the gravity together with all the risks and within reach of predators. Specifically birds have developed many complex rules to maintain this balance successfully, because other species in animal kingdom, such as butterflies, have more rudimentary rules. Explaining with a metaphor, they would be like the Chinese rigid hand fans, which are traditionally made by paper on bamboo frame and were broadly recognized while the Ming Dynasty. They are beautiful, useful and very widely used all around the world and for a long time ago, however, they are more breakable than another sorts of fan (folding). Also the Japanese rigid fans (*uchiwa*) were made with the same materials and they both originally might come from the Egyptian flabellum. Because of their decorative motives, beautiful delicate movements such a butterfly or smooth movements, oriental fans were considered, like signs of feminity and coquetry (Fig. 4). Concerning to the butterfly, however, it is well known the life span of butterflies is quite limited in time (i. e. 3-4 months, 12 months for specie *Vanessa Cardui* or 2 years of life for some Arctic butterflies).

Fig. 4. Eros offering a fan and a mirror to a lady. Ancient Greek amphora from Apulia, Archeological Museum in Milan, Italy

6. THERMAL INERTIA

Bergmann's rule is is an eco geographical rule that states populations and species of larger size are found in colder environments, and species of smaller size are found in warmer regions, cast in terms of latitude, within a broadly distributed taxonomic clade. This is a very relevant question for survival and it is most often applied to mammals and birds (endotherms), although increased body size has been proved in insects to have profound consequences on fitness, female fecundity and male mating success (for revision see [13]). The rule is named after nineteenth century German biologist Carl Bergmann, who described the pattern in 1847, but he was not the first to notice it and some researchers have also found evidences for the rule in studies of ectothermic species. Bergmann's rule is a classic example of adaptive geographic variation, although the accuracy of Bergmann's rule application for all species is still under debated, particularly in the case of ectotherms [14].

For instance, the phylogenetic inertia seem to route some species such as bumblebees (Fig. 5), which are distributed from the arctic to the tropic, to have thermoregulatory capacities exhibiting the Bergmann´s rule: the largest species are found in places with high water availability (colder) during the driest time of the year. But their body size might also be related to other variables, beside the energetic advantages of thermoregulation (large bodies organisms will absorb heat more slowly than smaller organisms; Scriven et al., 2016), such as flower availability or other phenomenology [13].

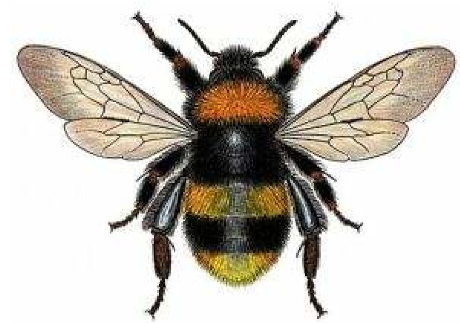

Fig. 5. Bumblebee, a member of the genus *Bombus* part of *Apidae*. They are found in higher altitudes or latitudes in the Northern Hemisphere, however, they are also found in South America where a few lowland tropical species have been identified. Phylogenetic inertia points out to an effect to their thermoregulation as a fact for their survival (larger bumblebee and body size generate more heat: Creates a lower surface to volume ratio that reduce heat loss [14]

Another example of thermal inertia in nature are in the sharks: they appear to be least active while their bodies temperature are highest and most active while temperatures are cooling. Two sorts of behaviors have been described for these predators: "hunt warm, rest cold" and "hunt cold, rest warm", because temperature changes may modify behaviors to take advantages or thermal regimes [15]. This capacity of adaptability might be affecting other behaviors related to survival, such as choice for waters: pregnant female sharks are known to aggregate and select warm shallow waters during the afternoons to increase their body temperatures, potentially reducing gestation time of pups. Moreover male sharks tend to prefer warmer temperatures in waters as a strategy to increase rates of digestion before the nocturnal activity period [15].

In lizards (Fig. 6), which are one of the most successful species on the world, containing the most recent common ancestors of Archosaurs, Lepidosaur, Choristodera and all their descendants, have a body temperature regulations to adaptation. Larger sizes are associated with higher thermal inertia, and smaller sizes are associated with faster heat gain and loss, but again this advantage cannot be consider as such adaptable skill, without analyzing the environmental factor in evolutionary scenarios [16]. That is why a Phylogenetic eigenvector regression (PVR) calculations to include all these variables has been proposed to measure these adaption abilities in animal kingdom as a model pattern of autocorrelation in time, space and phylogeny [17].

Fig. 6. A chameleon, as an example of specialized clade of Old World lizards with 202 different species described as of June 2015. Reptiles, which are predators with ectothermic metabolisms, arose about 310-320 million years ago during the Carboniferous period. They have a very sophisticated thermal body regulatory system and they are able to change the color of their bodies accordingly to external signals

7. BRAIN AND INERTIAL FORCE

To all vertebrates, terrestrial life depends on continuous balance based on an allocentric (inertial) reference frame defined by gravity. The inertial motion might be coded by singe or groups of Purkinje cells in the cortex of the cerebellum. These Purkinje cells might represent a homogeneous population that could be encoding the inertial motion, as it was previously proved for transforming and selectively translating the spatial and temporal frame signals about head rotation from the semicircular canals [18].

Concerning to the motor system, it was suggested the control of the position of an inertial load by agonistic motor neurons implies reflexes of responsiveness according to changes in sensitivity of spinal motor neurons depending on the magnitude and stability demands to synaptic input coming from peripheral afferents according to loads and its magnitudes [19].

8. INERTIAL FORCE IN FITNESS

Inertial force is very present while fitness exercises and muscular training. Metaphorically writing, from the very beginning of planning to go sporting, the inertia is to stay rest, to keep no movement under the sun, for instance. Like some people states “we must heed the body”, the inertial force is very strong against our own evolution. But once that impulse of non activity is overcome, the physical activity is very beneficial and probably adaptive for our health, because “no pain, no gain”or “because swole is the goal, size is the prize, it´s gainz o´clock, ..., let´s go!!!” (Robert Frank-615, motivational sportive sentences).

The exercise is a continuum tendency of fighting against the natural laws, such as gravity, inertia etc. Abduction and adduction movements are examples of body movements of detachment or approach to an axis defined based on flexions and extensions of our muscles against inertial forces (Fig. 7). The resistance to that forces defines the intensity of our exercise and help us to build our muscles. Muscular fitness is mostly described in terms of muscle strength, as the ability to produce a force against a resistance, while muscle power explosiveness is the rate at which the force can be generated [20]. Inertial force is much easily noticeable in aerobic exercises, where body movements are clearer and resistance to inertial force are more visible. For anaerobic exercises this might be not so visible, but this hypothesis might require further research: perhaps the way of breathing while exercising might be a signal which points out our effective or ineffective work against inertia force (aerobic *vs* anaerobic exercises).

Fig. 7. Schematic representation of body movements against the inertial force: abduction is separating in movement the structure (arm and leg in this example), against inertia from a midline while adduction, on the contrary, is done when movement goes toward the midline of the body, to restore inertia

In obese people, the excessive body weight and increased inertia of the body are variables to consider before planning any sport schedule. In a study about the age cohort of children and adolescents with obesity it was shown the obese group displayed impaired muscular fitness compared to their healthy-weight peers [20]. In addition metabolic disturbance related to carbohydrate metabolism oxidations and breathing might be present as problems to consider before sporting in patients with obesity. Body weight might have an effect not only over muscular capacity but also relies on other musculoskeletal factors such as motion, flexibility, balance, coordination, gait and posture [20].

9. CONCLUSIONS

Inertial is a very important force present in nature and evolution, conditioning every object on movement or static state. While playing hula hoop the inertial force can be used to build beautiful trick or performances. It is present both to keep the symmetrical circle shape and to preserve the movements/stillness. Fitness and sports are partly based in the resistance to the inertial and other forces, because the muscle develops in opposition to these facts. When practicing sport activities inertial force might be present at the beginning of exercises, through a series of body changes, in a cycle from rest point to the higher activity point to rest point again, while many events happen in the body. Inertial force happens in brain activity in motor system and Purkinje cells of the cerebellum. Having this knowledge of inertial force and nature would help us to use if for our benefits in sport evolution having some clues to improve our planning exercises routine and to increase benefits of practicing sports.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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