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Evaluation of the Impact Acceleration Forces Attainable by Use of Mini-Trampoline

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=국문초록=

Mini-Trampoline 운동중 인체가 받는 중력가속도의 변화

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수직뛰기 운동을 위한 mini-trampoline은 운동중 인체에 미치는 중력가속도를 변화시킴으로써 그 효과를 나타낸다고 하므로, mini-trampoline 운동중에 피검자가 받는 중력가속도를 다음과 같은 방법으로 측정하였다.

피검자로 하여금 mini-trampoline 상에서 최대의 높이로 수직뛰기를 반복시키고, 그 뒷벽에는 3인치 간격의 눈금을 표시하여 뛰는 높이를 알 수 있게 하였다. 수직뛰기를 하는 동안에 super-8 mm 영사기로 초당 48 frames의 속도로 촬영한 후 각 frame에 나타난 피검자의 두정부 높이를 알아내었다. 수직뛰기하는 동안 시간에 대한 머리높이의 변화를 graph에 그려서 상승뛰기 운동시의 최대속도를 계산하였다.

이 결과로 부터 Arizona State University의 Crash Survival Investigator's School에서 고안한 다음의 공식을 사용하여 중력가속도(G)를 계산하였다.

$$G = \frac{0.7854 \cdot V^2}{32.2\,S}$$

V = 상승운동시 나타난 최대속도(fps)

S = 하강운동시 정지거리(ft)

본 연구에서 V는 약 9 fps였고, S는 0.61 ft였으며 따라서 G는 $3.24+G_z$였다.

인체가 견딜 수 있는 중력가속도의 한계가 $+G_z$방향으로 0.1초동안 20 G 이며 $-G_z$방향으로 0.1초동안 15 G 임을 고려할 때 mini-trampoline 운동으로써 얻을 수 있는 중력가속도는 인체에 유해할 만큼 큰 것이 아니라는 것을 알 수 있다.

INTRODUCTION

Miniature trampoline has become a popular exercise device in recent years. Carter,[1] one of the leading proponents of the devices, claims that the mini-trampoline is the most efficient, effective form of exercise yet devised by man. He hypothesizes that the reason for the effectiveness of the trampoline as an exercise device is due to the increased gravitational force exerted on every cell in the body which is imparted during the upward thrust. Despite the many claims as to the perported effectiveness of the devices for both conditioning purposes and as a general therapy for many diseases,[2~4] surprisingly little work has been done

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regarding either effectiveness or the acceleration effects of the mini-trampolines. The purpose of this study was to measure the G-force imparted by one variety of mini-trampoline.

Acceleration physiology, like other branches of science, has its own peculiar terminology. Acceleration occurs when the velocity or direction of motion of a body changes. Linear acceleration occurs when the velocity of a body is varied without a corresponding change in its direction of motion. Impact, or abrupt accelerations, are arbitrarily designated as accelerations having a pulse duration of 1 second or less.[5] It is this type of acceleration which is the subject of this paper.

The direction of linear acceleration may be described using a three-coordinate system.[6] When linear acceleration is in an upward or headward direction, it is called positive G_z ($+G_z$) or "eyeballs down". When in a downward direction, it is called negative G_z($-G_z$) or "eyeballs up". In a forward direction it is called positive G_x($+G_x$) or "eyeballs in", and in a backward direction, negative G_x($-G_x$) or "eyeballs out". Likewise, motion to the right is positive G_y($+G_y$), or "eyeballs left", and motion to the left is negative G_y($-G_y$) or "eyeballs right". Military physiologists, particularly those involved in aviation medicine and aerospace medicine are the group most involved with researching the effects of gravitation on the body. The primary purpose of this research, of course, is to evaluate the physiological effects of the increased gravitational forces on aviators during such maneuvers as catapult launches from aircraft carriers, high-G combat maneuvers, ejection from high performance aircraft, and determination of the deccelerative forces which the human can tolerate resulting from aircraft crashes. In recent years, great interest has also been placed on determining the effects of sustained high-G launches as experienced in the space program, as well as the effects of prolonged weightlessness on astronauts.

Although extensive research into many aspects of acceleration physiology has been conducted, it has generally been of a nature which would answer questions pertinent to aviators and astronauts. An extensive search of the literature revealed only one other study[7] of the effects of repeated impact accelerations of a moderate level in the G_z axis as would be encountered on a trampoline. In that study small accelerometers were taped to subjects bouncing on standard size trampolines, and maximum forces of up to $8+G_z$ were reached.

MATERIALS AND METHODS

A well-conditioned subject familiar with the use of the mini-trampoline performed repeated rhythmic bouncing at the maximum height attainable with the device used. This was filmed with a super-8 mm camera at a rate of 48 frames per second, against a backdrop with markings at 3" intervals. The film was projected frame by frame, and the height of the subject's head against the backdrop was noted (Table 1). These results were then plotted on graph paper (Fig. 1). Formulas[8] devised by the Crash Survival Investigators' School, Arizona State University, Temple, Arizona were used to determine the accelerative forces. It was assumed that the acceleration/decceleration pulse was constantly changing (as in an arrested aircraft carrier landing) and thus would be represented by a Half-Sine Pulse (Fig. 2). The fourmula[8] for determining the $+G_z$ is:

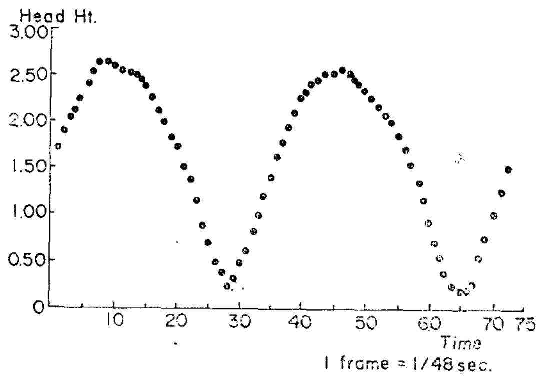

Fig. 1. Changes of subject's head against time scale while rebounding.

Table 1. Change of subject's head height while rebounding

Frame	Head-Height(In Feet)	Frame	Head-Height(In Feet)	Frame	Head-Height(In Feet)
1.	1.75	25.	0.70	49.	2.40
2.	1.90	26.	0.50	50.	2.35
3.	2.05	27.	0.38	51.	2.30
4.	2.13	28.	0.25	52.	2.20
5.	2.25	29.	0.33	53.	2.13
6.	2.40	30.	0.50	54.	2.00
7.	2.55	31.	0.63	55.	1.85
8.	2.63	32.	0.82	56.	1.70
9.	2.63	33.	1.00	57.	1.53
10.	2.60	34.	1.20	58.	1.35
11.	2.55	35.	1.40	59.	1.15
12.	2.53	36.	1.63	60.	0.93
13.	2.50	37.	1.78	61.	0.70
14.	9.45	38.	1.95	62.	0.55
15.	2.38	39.	2.10	63.	0.38
16.	2.25	40.	2.25	64.	0.23
17.	2.10	41.	2.32	65.	0.20
18.	2.00	42.	2.40	66.	0.20
19.	1.83	43.	2.45	67.	0.25
20.	1.75	44.	2.50	68.	0.55
21.	1.50	45.	2.50	69.	0.75
22.	1.38	46.	2.55	70.	1.00
23.	1.13	47.	2.50	71.	1.25
24.	0.88	48.	2.45	72.	1.50

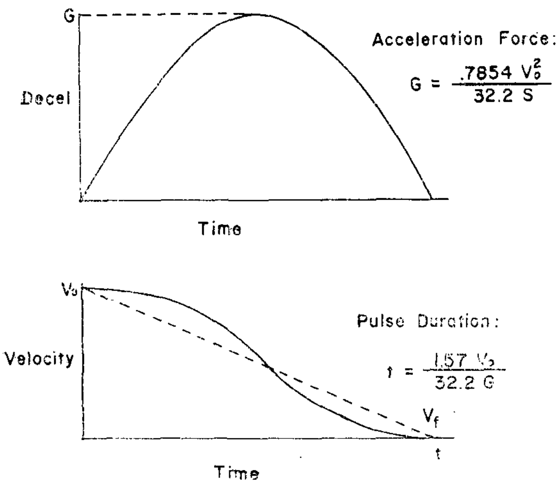

Fig. 2. Half-Sine Pulse. Adapted from US Naval Flight Surgeon's Manual(Ref. 8).

$$G=\frac{.7854(V^2)}{32.2S}$$

Where V = maximum *velocity in fps*, S = *stopping* distance in feet, and G = acceleration force in G.

V was computed as the upward slope of the curve determined in Figure 1. S was determined by placing objects of a measured height beneath the trampoline and progressively increasing the height of the objects until the trampoline just touched the top of the objects at the the bottom of the bounce. This distance was then subtracted from the height of the trampoline from the floor.

RESULTS

As the subject was filmed at a film speed of 48 frames per second, $\triangle t$ was 1/48 second between each frame. The velocity was determined by measuring the slope of the curve, $\triangle s/\triangle t$ at its maximum (Fig. 1). This was calculated as approximately 1 ft per 5/48 sec (.104 sec), reducing to about 9 fps (precision varies slightly with the slope selected). S, the stopping distance, was found to be .61 feet (the vertical distance traveled by the trampoline mat) which was determined using the method described above. Plugging the values obtained into formula (1), we have

$$G=\frac{.7854(9^2)}{32.2(.61)}=\frac{63.6}{19.642}=3.24+G_z$$

DISCUSSION

The effects of sustained acceleration on the body are in many ways similar to those of exercise[9]. Although there does not appear to be anything in the literature which evaluates the training effect of sustained acceleration, because of the demonstrated similarity in many ways of sustained acceleration to exercise, it would appear to be a reasonable assumption that there would be a training effect as a result of regular sustained acceleration. Somewhat less well understood, however, is the effect of repeated impact acceleration of moderate intensity. Whether repeated impact accelerations are similar to exercise (as with sustained acceleration), and/or whether the effect is beneficial (as hypothesized by Carter and other mini-trampoline enthusiasts) has yet to be determined. However, as human tolerance to impact accelerations is 20 G's over 0.1 second in $+G_z$ direction and 15 G's over 0.1 second in the $-G_z$ direction[10], and since the forces imparted by the mini-trampolines are well below these maximum limits, they are at least not of such a severity as to be injurious.

Numbers are magical, and seem to confer scientific precision at times when it may not be wholly appropriate, and such may be the case with the calculations in this paper. Too many variables exist in these measurements (weight and physical condition of the subject, voluntary effort, rebound characteristics of the type of mini-trampoline used), in addition to the inherent chance for inaccuracy caused by the choice of slopes from which V is determined and the squaring of V in the Formula, for these calculations to be more than a rough approximation of the forces being measured. Nevertheless, despite the inherent inaccuracy, these values correlate quite well with the greater G forces which were obtained on full sized trampolines in the previously cited study[7], and demonstrate that a significant impact acceleration is produced by mini-trampolines. What remains to be investigated is their physiologcial and training effects.

SUMMARY

It has been hypothesized that the effectiveness of the popular mini-trampoline as a conditioning device is due to the increased gravitational forces which are imparted to every cell in the body during its use.This study evaluated a means of determining the acceleration forces on a subject using a mini-trampoline. By cinematic evaluation, a plot of the changes in distance over time was obtained. Using the formulas developed at the Arizona State University Crash Survival Investigators' School, the maximum acceleration forces were determined to be approximately $3.2+G_z$.

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