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A COMPARATIVE EVALUATION OF FOUR AUTOMATIC WEIGHING SYSTEMS

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ABSTRACT

Four commercially available automatic weighing systems were comparatively evaluated with a Mettler H20T semimicro balance, manually operated, serving as a control.

The approach to the study was to choose 50 test units randomly from five different products (tablets and capsules) with average weights ranging from as low as 125 mg per unit to as high as 750 mg per unit. Each unit from each product was assigned a number from 1 through 50 and was weighed on all five weighing systems in a random sequence. In a second series of measurements

one unit of each product, selected randomly, was weighed 20 times on each of the five weighing systems. Data from both series were statistically analyzed and evaluated.

Results were similar in both series of experiments and indicated that the Cahn automatic weighing system exhibited the most variability. The Scientech automatic weighing system was the second most variable followed by the other two automatic weighing systems; Sartorius and Mettler. The Mettler H20T, the control, was the least variable. The geometric averages for each product among the weighing systems were statistically different ($P \leq 0.05$); however, the magnitude of these differences was considered not large enough to be of any practical pharmaceutical interest.

The important features of each of the automatic weighing systems are presented and an attempt is made to explain the variabilities observed.

INTRODUCTION

A total weight of a tablet or a capsule is one of its most important physical properties for it controls the amount(s) of active ingredient(s) and the one or more inert ingredients present in the formulation. While the active ingredient(s) provides the therapeutic effect, the inert ingredients function to insure optimum performance of the dosage form.

"Drug substances are most frequently administered orally by means of solid dosage forms such as tablets and capsules." (1)

In manufacturing tablets and capsules, blends of active drug and excipient(s) make up the target weight. To insure that the weights are within specified limits, periodic checks are made during a production run and mechanical adjustments are made keeping weight variation to a minimum.

Large-scale production methods are now necessary to meet the increasing demands for solid dosage forms. To assure that the products resulting from these large-scale methods meet high quality standards the use of highly efficient test and regulating equipment is gaining momentum, particularly since weighing solid dosage forms individually on analytical balances is not only tedious, but may introduce considerable operator error as well. Automatic weighing systems have the potential for being more efficient than manual systems. In addition, they can be interfaced with electronic data receivers, deck writers, computers and calculators in ways such that the data related to each product can be analyzed quickly and accurately. Further, this information can be obtained in print-out format serving as a permanent record, if so desired.

The objective of this study was to evaluate and compare data from four commercially available automatic weighing systems against those from a typical analytical balance. The data generated were statistically analyzed so that a positive comparison of each weighing system could be made.

METHODS AND MATERIALS

Five different pharmaceutical products were selected representing average unit weights ranging from 125 mg to 750 mg (Table I).

Fifty units of each product were randomly selected from a bulk source and each marked with indelible ink contributing insignificant weight with a number from 1 through 50. Each was kept in a high-density, polyethylene bottle with a metal, screw cap lined with pulp, waxed-paper and a glassine, foil-laminate, inner seal between tests and when being transferred to the various testing sites (Table II). Each unit from each product was randomly assigned to each of the five weighing systems considered.

TABLE I

Identification of Products in Study

Product No.	Dosage Form	Theoretical Weight Per Unit	Size
I	Film Coated Tablet	136.0 mg	8/32" diameter round, biconvex
II	Dry Filled Capsule	290.0 mg	#3
III	Film Coated Tablet	380.0 mg	13/32" diameter round, biconvex
IV	Dry Filled Capsule	425.0 mg	#1
V	Film Coated Tablet	752.0 mg	9/32" x 12/32" capsule shaped

TABLE II

Instrument Identification and Site of Test

Weighing Systems	Identifying Code
a. Mettler Semimicro,[1] Model H20T West Point, Pa.	Mm
b. Scientech Automatic,[2] Model 280 West Point, Pa.	Sa
c. Mettler Automatic,[1] KWT 10 Model 1 Hightstown, New Jersey	Ma
d. Cahn Automatic,[3] Model FA West Point, Pa.	Ca
e. Sartorius Automatic,[4] Model 5100 Westbury, New York	Ra

[1]Mettler Instrument Corporation
Princeton-Hightstown Road, Box 71
Hightstown, New Jersey 08520

[2]Scientech, Inc.
5649 Arapahoe Avenue
Boulder, Colorado 80303

[3]Cahn Instruments, Division of Ventron Corporation
16207 South Carmenita Road
Cerritos, California 90701

[4]Sartorius, Division of Brinkmann Instruments, Inc.
Cantiague Road
Westbury, New York 11590

Since "Sa" did not automatically print out data, at the time of testing, the data were manually recorded from the digital display. "Ca" was interfaced, at the site, with a PDP-8E computer and the ASR-33 teletype to obtain automatic print out of the data. In

the cases of "Ma" and "Ra" all data were printed out. Weighings were conducted by one operator.

Each automatic weighing system included a feeding system, a weighing balance, an electronic control system and a system to collect and store the units after testing.

All four automatic weighing systems used similar but unique systems for handling the dosage units to be weighed. In the case of "Ma", "Ca" and "Ra", the units are moved by vibration but guided to the weighing pan differently (Table III). Channels are used in "Ma" and an adjustable rotor with a vacuum pick-up in "Ra", where a brush also cleans the pan before the unit is placed in position for weighing. With "Ca" the test unit is picked up and moved to the weighing pan by vacuum. In "Sa" the units are put into a hopper from where each is carried to the drop sensor station by a sorting plate, then moved by a transport disc to the weighing pan.

The weighing system used in each of the automatic weighing systems is an electronic balance employing automatic force compensation to register weight.

Electronic control systems also control the feeding and ejection systems as well as the transfer of the generated data to the digital readouts or to interfaced calculators and/or computers.

Systems for collecting test units after weighing for each of these automatic weighing systems can be custom made for an additional cost.

TABLE III

Features* of the Four Automatic Weighing Systems Tested

Features	Cahn**	Mettler	Scientech	Sartorius
Maximum Weighing Speed (Units/Min)	25	35	60	32
Integration Time (Milliseconds)	Not Specified	400-900	35-280	200-500
Maximum Capacity (g)	2.0	10.0	1.9	1.4
Readability (mg)	1.0	0.1	1.0	0.1
Maximum Sample Size	12mm x 20mm x 23mm	Not Specified	19mm Diameter	Not Specified
Zero Setting	Manual	Automatic	Manual	Automatic
Feeding System	Guide Chutes	Feeding Channels	Sorting Plates	Adjustable Rotor System

*More details can be found in the respective manufacturer's catalogs. Cost of each system would vary depending upon the features required.

**No longer commercially available.

Some features of these automatic weighing systems tested are shown in Table III.

Two series of data designated as α and β were generated from each weighing system.

In the α series each of the 50 units of each product randomly chosen, was weighed in sequence on each weighing system. A Mettler semimicro balance, model H20T was used as a control.

Weight determinations were made on this balance initially (Mm) and were repeated (Mmr) after the test units were weighed on the four automatic weighing systems. The data generated would allow an assessment of the overall performance of all weighing systems while at the same time showing the variability of the test units as well.

In the β series one unit was picked at random from the 50 of each of the five products as follows:

Product	Identity of Sample Picked
I	42
II	15
III	20
IV	31
V	10

This unit was weighed 20 consecutive times on each of the five weighing systems and the weights recorded.

Since the same unit was subjected to all weighing systems, the data obtained would assess the variability within each weighing system without introducing the variation of one unit to another.

RESULTS AND DISCUSSION

The statistical analysis of the data from the α series is shown in Tables IV, V and VI while that for the β series is shown in Tables VII and VIII.

The statistical analysis associated with the data of the α series included: (a) the Levene test (2) for Randomized Block Design for comparing the variabilities associated with the weigh-

TABLE IV

Comparison of Average Absolute Mean Deviations* (α Series, N = 50) Associated with Weighing System for Each Product

Product	Weighing Systems					
	Mm	Sa	Ma	Ca	Ra	Mmr
I	▲0.19^{A}	0.38^{B}	0.23^{A}	0.84^{C}	0.22^{A}	0.20^{A}
II	0.41^{A}	0.55^{A}	0.44^{A}	1.82^{B}	0.43^{A}	0.40^{A}
III	0.54^{A}	0.51^{A}	0.54^{A}	2.34^{B}	0.44^{A}	0.47^{A}
IV	0.42^{A}	0.67^{B}	0.41^{A}	1.94^{C}	0.48^{A,B}	0.41^{A}
V	0.75^{A}	1.03^{A}	0.71^{A}	3.81^{B}	0.85^{A}	0.69^{A}

*Two average absolute mean deviations with at least one common superscript are not statistically significantly different at P = 0.05. Two average absolute mean deviations with no common superscripts are statistically significantly different at P < 0.05.

▲The average absolute mean deviation calculation is based on the Levene test for Randomized Block Designs.

ing systems, (b) the ANOVA test (3) for Randomized Block Design for comparing the averages associated with the weighing systems and (c) Duncan's multiple range test (4) for pairwise comparisons of the weighing systems based on the results in (a) and (b).

The statistical analysis associated with the data generated in the β series consisted of (a) the Levene test for Completely Randomized Design for comparing variabilities among the weighing systems, (b) the ANOVA test for Completely Randomized Design for comparing the averages associated with the weighing systems and (c) Duncan's multiple range test for pairwise comparisons of the weighing systems based on the results in (a) and (b).

TABLE V

Comparison of Average Absolute Mean Deviations* (α Series, N = 50) Associated with Products for Each Weighing System

Weighing Systems	Products I	II	III	IV	V
Mm	▲2.98^{A}	3.60^{A}	5.45^{B}	6.74^{B}	10.57^{C}
Sa	2.99^{A}	3.52^{A}	5.27^{B}	6.66^{B}	10.59^{C}
Ma	2.97^{A}	3.62^{A}	5.39^{B}	6.79^{B}	10.57^{C}
Ca	3.26^{A}	4.77^{A,B}	5.40^{B,C}	7.00^{C}	10.57^{D}
Ra	3.00^{A}	3.64^{A}	5.38^{B}	6.79^{B}	10.52^{C}
Mmr	2.96^{A}	3.59^{A}	5.31^{B}	6.72^{B}	10.54^{C}

*Two average absolute mean deviations with at least one common superscript are not statistically significantly different at P = 0.05. Two average absolute mean deviations with no common superscripts are statistically significantly different at P <0.05.

▲The average absolute mean deviation calculation is based on the Levene test for one way classification analysis.

TABLE VI

Comparison of Geometric Averages* (α Series, N = 50) Associated with Weighing Systems for Each Product

Product	Weighing Systems Mm	Sa	Ma	Ca	Ra	Mmr
I	133.92^{A}	134.21^{B}	134.25^{B}	135.40^{C}	133.78^{A}	133.81^{A}
II	286.70^{B,C}	287.15^{C}	286.56^{B}	289.54^{D}	285.18^{A}	285.02^{A}
III	380.26^{B,C}	380.71^{C}	380.07^{B}	383.94^{D}	379.74^{A,B}	379.38^{A}
IV	424.58^{D}	425.15^{E}	423.97^{C}	421.86^{A}	422.97^{B}	422.72^{B}
V	756.25^{B,C}	756.84^{C}	755.91^{A,C}	756.51^{B,C}	755.53^{A,B}	754.76^{A}

*Two geometric averages with at least one common superscript are not statistically significantly different at P = 0.05. Two geometric averages with no common superscripts are statistically significantly different (P <0.05).

TABLE VII

Comparison of Average Absolute Mean Deviations* (β Series, N = 20) Associated with Weighing System for Each Unit of Each Product

Product	Unit No.	Weighing Systems				
		Mm	Sa	Ma	Ca	Ra
I	42	▲0.02^{A}	0.51^{C}	0.07^{A,B}	0.66^{C}	0.25^{B}
II	15	0.02^{A}	0.48^{B}	0.11^{A}	1.08^{C}	0.26^{A,B}
III	20	0.01^{A}	0.44^{B}	0.11^{A,B}	1.24^{C}	0.24^{A,B}
IV	31	0.01^{A}	0.70^{A}	0.12^{A}	3.43^{B}	0.26^{A}
V	10	0.02^{A}	0.91^{B}	0.21^{A}	3.52^{C}	0.26^{A,B}

*Two average absolute mean deviations with at least one common superscript are not statistically significantly different at P = 0.05. Two average absolute mean deviations with no common superscripts are statistically significantly different at P < 0.05.

▲The average absolute mean deviation calculation is based on the Levene test for Completely Randomized Designs.

Since the same 50 tablets (or capsules) were tested on each of the five weighing systems in the α series, the "tablets" (or "capsules") formed a "block" giving rise to a randomized block design.

α Series: The statistical results associated with the variability analysis in Table IV indicate: (a) no statistical differences (P = 0.05) among "Mm", "Ma", "Ra" and "Mmr" for product I and II, (b) no statistical differences (P = 0.05) among "Mm", "Sa", "Ma", "Ra" and "Mmr" for products II, III and IV, (c) "Sa" to be statistically significantly different (P ≤ 0.05) from all other weighing systems for product I, and from all other

TABLE VIII

Comparison of Geometric Averages* (Beta Series, N = 20) Associated with Weighing Systems for Each Unit of Each Product

Product	Unit No.	Weighing Systems				
		Mm	Sa	Ma	Ca	Ra
I	42	134.40^{A}	134.85^{B}	134.99^{B}	135.35^{C}	134.75^{B}
II	15	283.75^{A}	284.60^{B}	285.27^{C}	289.40^{D}	284.05^{A}
III	20	377.09^{A}	378.15^{C}	$377.68^{B,C}$	$377.65^{A,B,C}$	$377.43^{A,B}$
IV	31	428.84^{A}	$429.50^{A,B}$	430.21^{B}	431.73^{C}	$429.40^{A,B}$
V	10	771.80^{A}	773.45^{B}	773.64^{B}	786.19^{C}	$772.58^{A,B}$

*Two geometric averages with at least one common superscript are not statistically significantly different at P = 0.05. Two geometric averages with no common superscripts are statistically significantly different (P <0.05).

weighing systems except "Ra" for product IV and (d) "Ca" showing the highest variability ($P \leq 0.05$) for all products considered.

The statistical results associated with the variability analysis in Table V indicate an increase in variability as a function of increased product weight.

The statistical results associated with the comparison of geometric averages are in Table VI. It is apparent that the accuracy of the equipment is not a function of the product's weight and no consistent pattern is observable. While the geometric averages for some of the products are statistically different ($P \leq 0.05$) among the weighing systems studied, the

magnitude of these differences is not considered large enough to be of any practical pharmaceutical interest.

β Series: In this series one unit of each product was weighed twenty times on each of the weighing systems and the data analyzed.

A comparison of the average absolute mean deviation associated with each weighing system for each unit of each product (Table VII) shows that "Mm" maintained the lowest variability justifying its consideration as the control. The variabilities associated with "Ma" and "Ra" were slightly higher than "Mm." "Sa" exhibited a higher variability than that of "Mm", "Ma" and "Ra"; while "Ca" maintained the highest variability among all weighing systems. Thus, the significant differences ($P \leq 0.05$) found in the α series are generally reflected in the variability results of the β series.

The geometric averages associated with the weighing systems statistically compared for each product and presented in Table VIII, indicate that there are statistical differences with respect to their geometric averages between the weighing systems, for each unit of each product. The highest percentage differences considered statistically significant ($P \leq 0.05$) are observed between "Mm" and "Ca" compared to other automatic weighing systems. Once again, the magnitude of these differences is not considered large enough to be of any practical pharmaceutical interest.

The significant differences observed in "Ca" and "Sa" could be due partly to the disturbances caused by the conveying system used in the respective weighing systems. As observed in Table III, integration time, which is a function of residence time, may also be partly responsible for the variabilities associated with each weighing system. These laboratory experiments suggest that the residence time of a unit on the weighing pan is important because a weighing system must attain equilibrium before accurate measurements can be made.

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