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Physical Body Parameters of Red-Crowned Cranes *Grus japonensis* by Sex and Life Stage in Eastern Hokkaido, Japan

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ABSTRACT. Red-crowned (or Japanese) cranes *Grus japonensis* are native to eastern Hokkaido, Japan—the island population, and mainland Asia—the continental population that migrates from breeding grounds along the Amur River Basin to winter in east China and the Korean Peninsula. The island population was reduced to about 50–60 birds in early part of the 20th century. Since 1950s, the population has increased to more than 1,300 as a consequence of human-provided food in winter, resulted in change of their habitats and food resource. From the carcasses of 284 wild cranes from the island population, collected in Hokkaido since 1976 until 2010, we measured six physical parameters (body weight and lengths of body, wing, tarsus, tail and exposed culmen) and divided into groups by sex and three developmental stages (juvenile, yearling and adult). All parameters of males were larger than those of females at the same stage. Total body length of females tends to grow up earlier than males, in contrast to body weight. Obvious time trends were not observed in these all parameters during 34 years for these six categories measured, except total length of male juveniles, which showed a significant increasing trend. These results provide the first extensive data on body size and mass in the wild red-crowned cranes.
KEY WORDS: body size, Gruinae, red-crowned (or Japanese) cranes, sexual difference, stage difference.

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Red-crowned (or Japanese) cranes *Grus japonensis* are highly protected birds and are listed in the red data books as an endangered species by the International Union for Conservation of Nature and Natural Resources (IUCN) and a vulnerable species by the Japanese Ministry of the Environment. There are two widely-separated populations of this species: a migratory population on the east Eurasian continent (the continental population) and a non-migratory population in eastern Hokkaido, Japan (the island population) [5]. The continental population was primarily distributed along the Amur River basin in Russia and China in summer and wintered along the east coast of middle China and on the Korean Peninsula [12, 18].

The island cranes were originally found throughout Hokkaido Island until the late 19th, however, hunting and wetland reclamation through the 18th and 19th centuries, led to a rapid decline from thousands to probably 50–60 birds in eastern Hokkaido by the beginning of the 20th century [14]. Artificial feeding in winter began in the early 1950s, and fortunately, the island population has remarkably increased to reach about 1,300 birds [13]. Now, urgent increase of the density in both wetland and dry fields [11, 15] is one of the main concerns about preservation of the island population, as the maximum numbers of cranes in eastern Hokkaido were estimated by Population Viability Analysis (PVA) to be 1,600 in the 2020s [17]. While the population has expanded its range to breeding areas in northern Hokkaido and the south Kuril Islands [4, 12, 16], in the last few decades, several pairs of cranes in the core areas of the breeding range started to breed in dry fields presumably because marshland habitats were occupied by highly territorial breeding pairs [14]. Now, residents in dry fields take substantial part [15]. As the result, their food resource has changed considerably: farmland-breeding birds frequently consume food from agricultural source, such as gleaning corn after the harvest and earthworms, whereas marshland-breeding birds eat mostly small aquatic animals, such as fish, amphibians and insect larvae [21]. Therefore, these changes in their habitat could have given any impact on crane's body growth and possibly health.

Red-crowned cranes in the island population died mainly due to collisions with power lines, traffic accidents with cars or trains or unidentified diseases [17]. Since 1976 just after the foundation of the Kushiro Zoo, the cranes, which were dead or dying in countryside of eastern Hokkaido, were collected and dissected by Kushiro Zoo. We studied 284 wild cranes to measure six physical body parameters including total body length and body weight classified by sex and three developmental stages for statistical analyses.

MATERIALS AND METHODS

In external features, red-crowned cranes of both sexes are nearly alike. The gender was determined by anatomical

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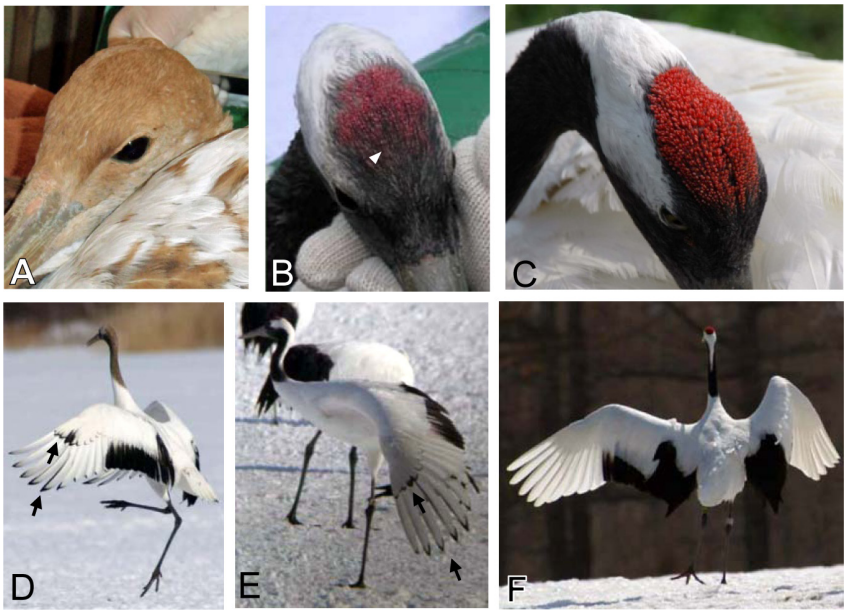

Fig. 1. Appearances of red-crowned cranes in each developmental stage. Images of juveniles (A, D), yearlings (B, E) and adults (C, F) were presented. Adults showed bright red crown in the forehead (C), and their primaries and upper primary coverts were all pure white (F). The crown of yearlings was not completely exposed and covered with blackish feathers (white arrowhead in B). Juveniles had brown forehead without the crown (A). Juveniles and yearlings had black tips of primaries and upper primary coverts (black arrows in D and E).

inspection of genitalia. Developmental stage was determined by feather pattern and features on the forehead and crown, as previously described [5, 12] (Fig. 1). Adults (two years old and older) were mostly covered with white feathers, except for the black neck, secondaries and tertials (Fig. 1F). The crown was bright red without feathers (Fig. 1C). Yearling birds (one year old) were covered with white feathers for most body parts and were very similar to adult birds, except black spots on the tips of the primaries and primary coverts (Fig. 1E). In addition, their crowns were not all completely exposed and in some cases were still dull red (Fig. 1B). Juveniles, which were able to fly as distinguished from late chicks, were a combination of white, partly tawny, cinnamon brown and grayish (Fig. 1A and 1D) [5, 12]. We were not able to determine developmental stage of some cranes with bright red crown and black tips on some of the outer primary coverts, because these could either be yearlings or older depending on the undetermined rate of molting of the coverts. These cranes were excluded.

According to the criteria for developmental stage of red-crowned crane in the previous paragraph, we studied 92 juveniles (36 males, 56 females), 31 yearling (one year old) (15 males, 16 females) and 161 adult (75 males, 86 females) cranes, which were dead or dying in the countryside of eastern Hokkaido, Japan, from 1976 to February 2010, under the permission from the Agency for Cultural Affairs (Tokyo, Japan) and the Japanese Ministry of the Environment (Tokyo). They were all wild, excluding cranes kept in a zoo or other facilities for more than 30 days except for body weight, as body weight usually decreased while the cranes were held in captivity. Body weight was measured when cranes were received in the Kushiro Zoo. We excluded extremely emaciated cranes and apparently underdeveloped juveniles as well as cranes with loss of an anatomical part. Contents inside stomach and intestine were not removed. However, they could hardly affect crane weight, as average of stomach contents was 43.0 g (11.8–118.8 g, n=41).

All length and body weight were measured by tape measure and ruler (lengths of total body and wing) or vernier calipers (lengths of tail, exposed culmen and tarsus) and platform balance or electronic balance (weight), respectively. All measurement parameters except body weight were carried out conventionally as indicated in Fig. 2 [22].

Results are presented as mean ± SEM. Significance of mean differences between stages by sex for each parameter was determined by Tukey-Kramer test ($P<0.05$). Significance of mean differences by sex at the same stage for each parameter was determined by Student's *t*-test ($P<0.05$). Single regression analysis was carried out to test the statistical significance of time trends of body parameters. A *P* value of less than 0.05 was considered to indicate statistical significance.

RESULTS

All average values with SEM of six body parameters, including total body length, wing length, tarsus length, tail length, (exposed) culmen length and weight, for three stages

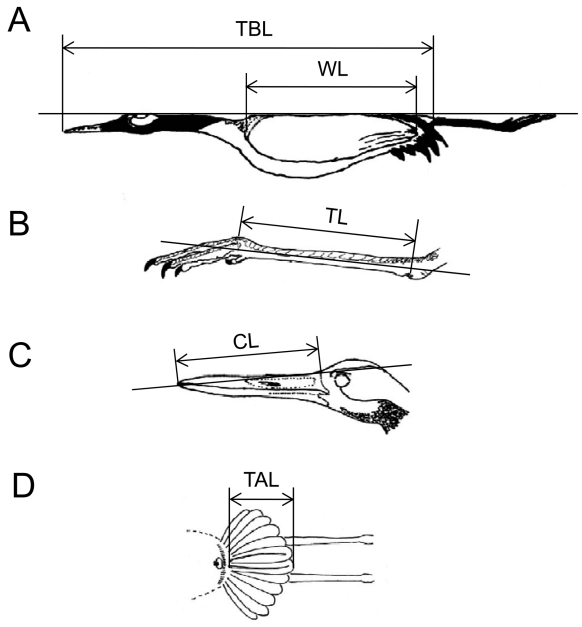

Fig. 2. Illustration of five body size parameters in red-crowned cranes. TBL: total body length WL: wing length (A) TL: tarsus length (B) CL: (exposed) culmen length (C) TAL: tail length (D).

by sex are summarized in Table 1. All parameters of males were bigger than those of females in the same stage for all three stages.

Comparing three stages for each parameter, culmen lengths of adults and yearlings for both sexes were significantly longer compared to juveniles (Table 1). Adult tail length was longer compared to juveniles and yearlings for both sexes, although significant differences between male adults and yearlings could not be confirmed in this study. There are no significant differences between three stages in wing length and tarsus length for both sexes. Sex-dependent differences were observed for total body length and weight. Total body lengths of male adults and yearlings were greater than that of juveniles, while there were no significant differences between three stages for females (Table 1). Conversely, adult body weight was significantly heavier than that of juveniles only for females.

Time trends of total body length and body weight during 34 years (1976–2010) were shown for adults (Fig. 3) and juveniles (Fig. 4) by sex. The variation among individuals in each growth stage of both sexes is small in total body length, on the other hand, that is larger in body weight. In adult, there seemed no particular trend of total body length and body weight for both sexes (Fig. 3). Other four parameters also did not show any particular changes in adults (data not shown). With regard to juveniles, which were expected to be sensitive to environmental changes more than adults, total body length in males showed significant increasing trend (Fig. 4), while obvious changes could not be recognized for the other parameters. The average total length of male juveniles has been increasing by about 3.9 mm in a year (Average total length in mm=3.943 × year − 6572.78, P=0.004). This corresponds to 132.6 mm in 34 years.

DISCUSSION

We provided the first extensive data on body sizes and mass in the wild red-crowned cranes in the island population. The results confirmed our previous observations suggesting male dominance in all body parameters examined with relatively small numbers of cranes in the island population [12]. Using specimens in museums [26] and in zoos [19], both of which were derived from the continental population, it has been also mentioned that most body parameters of adult males were usually larger than those of adult females. Male domi-

Table 1. Various measurements of body size and mass classified by sex and three developmental stages in red-crowned cranes in Hokkaido, Japan

		Total body length (mm)	Wing length (mm)	Tarsus length (mm)	Tail length (mm)	Culmen length (mm)	Weight (g)
Male	Adults	1,365 ± 6 (58) [aa)]**	618 ± 4 (65) **	296.1 ± 1.3 (56) **	253.1 ± 2.1 (60) [a)]**	162.4 ± 0.7 (64) [aa)]**	8,137 ± 138 (67) **
		(1,243–1,470)	(530–740)	(274.8–319.0)	(223.0–300.0)	(149.8–177.8)	(5,490–10,550)
	Yealings	1,352 ± 13 (12) [a)]**	605 ± 5 (11) **	288.3 ± 6.6 (10) *	243.0 ± 3.7 (11) **	161.0 ± 1.9 (12) [a)]**	8,237 ± 292 (13) **
		(1,270–1,427)	(580–630)	(245.0–301.6)	(221.5–260.0)	(150.7–173.6)	(6,800–10,500)
	Juveniles	1,303 ± 12 (32) **	617 ± 5 (32) **	294.2 ± 2.4 (27) **	246.2 ± 2.3 (29) **	154.9 ± 1.5 (32) **	7,735 ± 233 (35) **
		(1,100–1,413)	(555–700)	(260.0–318.8)	(220.2–275.0)	(134.1–168.0)	(5,560–10,300)
Female	Adults	1,247 ± 8 (67)	589 ± 3 (77)	276.3 ± 1.6 (57)	238.9 ± 1.7 (71) [aa,b)]	151.3 ± 0.6 (72) [aa)]	7,321 ± 133 (63) [aa)]
		(1,019–1,335)	(502–683)	(237.7–302.0)	(215.0–280.0)	(140.0–162.0)	(4,800–9,600)
	Yearlings	1,261 ± 7 (12)	576 ± 5 (14)	276.2 ± 2.7 (14)	227.4 ± 3.9 (13)	151.4 ± 1.5 (13) [a)]	6,895 ± 342 (12)
		(1,224–1,290)	(555–620)	(263.0–293.5)	(208.7–249.0)	(142.0–156.8)	(5,180–8,400)
	Juveniles	1,236 ± 7 (45)	587 ± 4 (49)	274.8 ± 1.7 (40)	230.9 ± 2.2 (46)	146.6 ± 0.9 (47)	6,507 ± 122 (45)
		(1,155–1,366)	(550–660)	(250.0–304.8)	(197.0–260.3)	(126.9–159.7)	(4,500–8,000)

Red-crowned cranes were all wild, excluding cranes kept in a zoo or other facilities for more than 30 days except for body weight, as body weight constantly decreased while the cranes were held in captivity. Body weight was measured when cranes were received in the zoo. Numers in parentheses indicate number of individuals studied. a) P<0.05, aa) P<0.01: statistically significant compared to juveniles by each sex (Tukey-Kramer test). b) P<0.05: statistically significant compared to yearlings by each sex (Tukey-Kramer test). * P<0.05, ** P<0.01: statistically significant compared to female value in the same stage (Student's t-test). Digit after the decimal point of each datum was dependent on the accuracy of measuring instrument used.

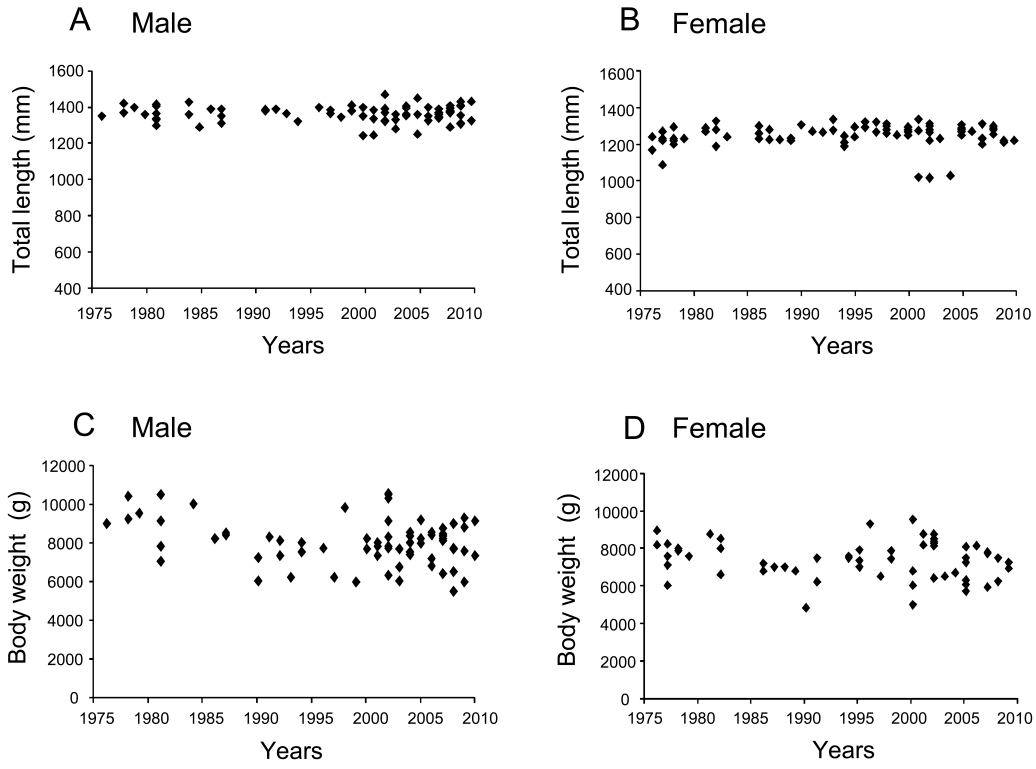

Fig. 3. Time trends of total body length and body weight of adults by each sex from 1976 to 2010. (A) and (C) indicate male total body length and body weight, respectively. (B) and (D) indicate female total body length and body weight, respectively.

nant property in body size might be common for all crane species. Exceptionally as a wild crane species, there were many reports on body size and mass of wild sandhill crane (*G. canadensis*) in North America [1, 6, 20], because they are game birds for hunting in North America. All parameters of male adults examined, such as lengths of culmen, tarsus and wing chord and body weight, were significantly larger compared to female adults, although information on younger birds was not provided. All other crane species also showed the same tendency without detailed information with enough number of birds available [26]. In most bird species, males are larger than females as like in most mammalian species. However, the reverse is the case in some birds, such as many ratites and raptors. Many hypotheses, either genetic or environmental factors, have been proposed to explain sexual size dimorphism in birds. Differences in foraging behavior and diet were suggested in some raptors as the cause of sexual dimorphism [10]. Differences in foraging behavior have not been recognized in red-crowned cranes [25]. Usually, however, male parents mainly fight for predators and other crane pairs to keep their eggs and chicks in red-crowned cranes, while both parent birds alternately brood their eggs in their nest [7, 12]. Thus, male dominance in size could be adaptive for this behavior. Previously, attempts were made to use male dominance in size for sex identification in many bird species including red-crowned crane [19]. Due to large individual difference, however, body size parameters and calculated values from the parameters could not be used for this purpose in captive red-crowned cranes [19]. The present study confirmed the conclusion again with large number of wild cranes.

Although some studies reported the growth of mass of red-crowned cranes that originated from continental stock, as well as sandhill cranes, siberian cranes (*G. leucogeranus*), white-(necked) naped crane (*G. vipio*) and so on, all of them focused on chick and juvenile stage using captive-reared cranes irrespective of sex [9, 23, 24]. Curro *et al.* [2] radiographically studied development of the femur, tibiotarsus, tarsometatarsus and fibula of the whooping crane (*G. americana*), sandhill crane and siberian crane in captivity compared to body weight and found that these leg bones grow faster to plateau level within around two months for three crane species. Similar results were obtained in two red-crowned cranes, which were raised by artificial incubation [9]. This is suitable for chicks to follow their parents to food sources or to escape from predators as soon as possible until they can fly [12]. After that, chicks develop their flight feathers in two to four months of age, preparing for long migrations for wintering. Red-crowned cranes could not be required to grow other body parts so soon compared to legs and wings.

Only limited information was available on the body pa-

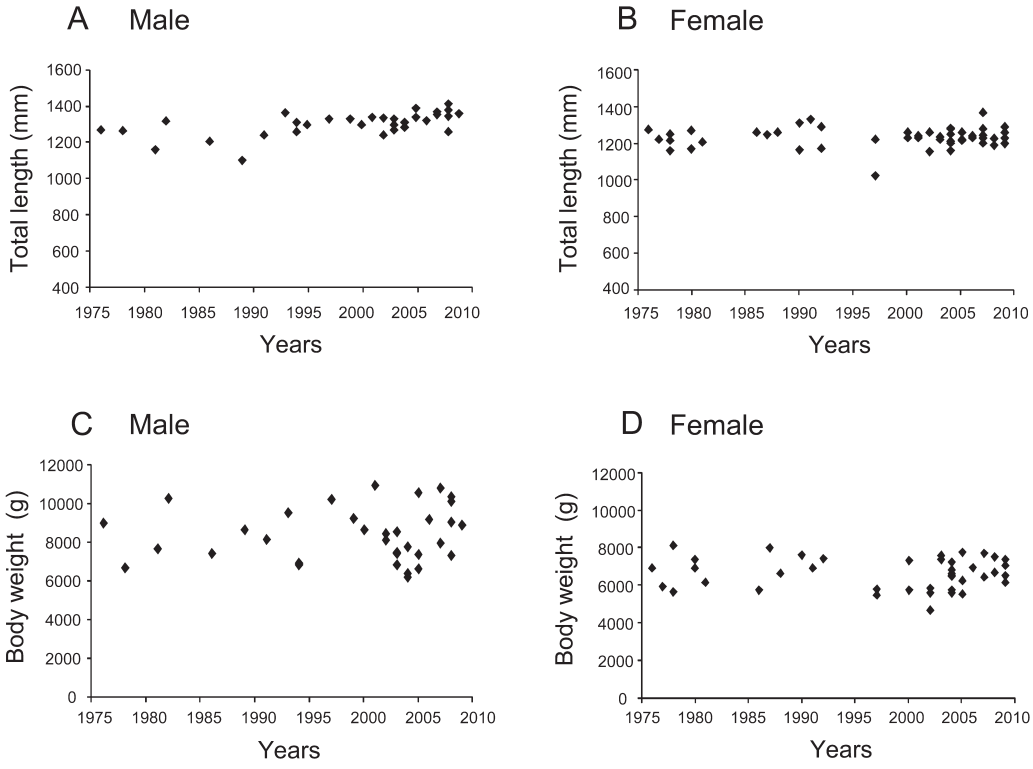

Fig. 4. Time trends of total body length and body weight of juveniles by each sex from 1976 to 2010. (A) and (C) indicate male total body length and body weight, respectively. (B) and (D) indicate female total body length and body weight, respectively.

rameters of red-crowned cranes in the continental population. Walkinshaw [26] reported that wing lengths of adult males and females in the wild continental population were 560–670 mm (average 618.6 mm, n=8) and 557–635 mm (average 609 mm, n=11), respectively. Tarsus length in the continental population was 267–301 mm (average 285.7 mm, n=8) for males and 255–297 mm (average 271.9 mm, n=11) for females. Body weights of continental cranes were too variable for comparison without average values mentioned (6,000–15,000 g) [3, 26]. Recently, average of body weight of wild adult cranes from the continent was reported as 9.09 ± 0.80 kg (n=10, 5 males and 5 females) [8]. Additionally, Chinese researchers measured the same body parameters of the continental cranes as ours; however, origins of six cranes (three males and females) and measurement method were not clear [27]. Thus, we were not able to confirm large differences in most body size parameters of red-crowned cranes between the continental population and the island population. Further studies with enough numbers of wild red-crowned cranes in the continental population were required for comparison with body size and mass of cranes in the wild island population.

Obvious time trends were not observed in these parameters during 34 years for these six categories measured in this study for adults. The island population increased almost consistently, from below a hundred in the early 1950s to now 1,300, supported by human-provided food in winter, although there was a temporal stagnation period due to collision with power lines [11, 12, 14]. This abrupt increase narrowed their territory available for each pair and affected feeding behavior [21]. However, there was no remarkable difference in the total amount of food resources between farmland-breeding pairs and wetland-breeding pairs, although food resource type differed between the two populations [21]. Our study indicates that changes in the last three decades, such as an increase in the density and changes of food resource type, did not markedly give negative impact on their nutritional status by the present time. However, only total body length of male juveniles shows increasing trend without significant effect on the other parameters. Since total length of male adults was constant, this observation might indicate that juveniles grow gradually earlier. As females originally grow faster to adult level in juvenile stage than males, remarkable effects might not have emerged. This should be verified in future study as well as the cause affecting the growth rate.

We should continue to measure body size parameters and mass more diligently to detect subtle changes in red-crowned cranes. This approach might be useful to find the problem around cranes, before some catastrophic disaster is caused. We started to measure length between bill tip and foot tip, in addition to conventional total body length from around 2000. This is useful for individuals, which lost their

tail. Additionally, skull length, wing span, bill height, bill width and gape length were also added as measurement item.

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